A Sustainable Fashion Industry for Hawai'i

A Senior Honors Project Presented to the Faculty of the
Department of Fashion Design and Merchandising
University of Hawai'i at Mānoa

In Partial Fulfillment of the Requirements
For Bachelor of Science with Honors
By Jennifer Bright
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Advisers:
Andrew Reilly, Ph. D.
Harry Ako, Ph. D.

Committee:
Andrew Reilly, Ph. D.
Marie Abigail Cristi, M.S.

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Abstract

Hawai‘i would benefit from a locally provided, sustainable textile industry that could help to support a local sustainable fashion industry. As a fashion designer striving for sustainable fashion in Hawai‘i, the preferred textiles used in creating designs inspired by Hawai‘i should be ones made in Hawai‘i. Products produced from these unique Hawaiian textiles would be limited, exclusive, and intrinsically invaluable. Textiles, as products of Hawai'i, would offer people who live in Hawai'i something additional to be proud of and the rest of the world something extraordinary to desire. Literature reviews were done on the possible fiber sources in Hawai'i, and the history of the Hawaiian garment industry. Further research was conducted on the locally produced Hawai'i specific items that are currently in the luxury market. Some ASTM textile tests were done on kapa made from Broussonetia papyrifera, wauke, and kapa made from Cannabis sativa, hemp. Water spray and impact tests could not be conducted because the kapa textile structure became immediately unstable. ASTM tearing, burning, stiffness, pilling, and abrasion tests were conducted and revealed that kapa textile is not suitable for regular garment use, but that may be viable for alternative textile usage. There is speculation on the use of hemp for textile production in Hawai'i. A presentation of the design philosophy of an emerging Hawai'i fashion designer, who promotes sustainable Hawaiian fashion through the intrinsic and extrinsic nature of the designs, as well as the intended company modus operandi, is offered as example and support for sustainable fashion.

Key words: Sustainable Textile, Sustainable Fashion, Hawai’i, *Broussonetia papyrifera*, wauke, kapa, *Cannabis sativa*, hemp

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Introduction

Sustainability seems to be a universally understood, widely interpreted, and broadly applied concept, however, the United States Environmental Protection Agency (2006) suggests that what they call, “productive harmony,” which promotes species wide behavior that is ethical in regards to other human rights issues, economic growth, and environmental concerns, can only be achieved if sustainable conditions exist between humans and the natural condition of which humans’ totality has fully originated. According to the Agribusiness Development Corporation (1997), sustainability involves the active restoration of endangered species, cultural practices, and communities in need. In fact, the State of Hawai’i previously created the Agribusiness Development Corporation or ADC as a proactive measure to investigate sustainable options and the business and economic impact of a move towards this sustainability concept, *especially* as it pertained to the availability of farmlands that had been previously used for sugar cane growth and were considered acceptable for growing hemp. Sustainability is a concept that is deeply rooted in Hawai'i, and is still being taught at the University of Hawai'i at Mānoa, (UHM).

Throughout a required Hawaiian studies course at UHM, various aspects of the ancient Hawaiian culture, and how the people of these islands cared for the land, were taught. When the first Hawaiians reached the islands, they had brought with them some of the plants that they needed and had been using for survival at the various stops along the way; the coconut palm tree, taro, paper mulberry, and the kukui or candle nut tree were among them (Ako, Kong, & Brown, 2005; White, 1996; Williams, R., Hawaiian Studies 107, 2013). These things were cultivated on the islands and used for shelter, food, clothing, currency, instruments, and other useful items, to create a lifestyle that was sustainable with the pre-western contact population, which is thought to have been around 250,000 to one million people, depending on the archaeologist (Dye, 1994;

Williams, R., Hawaiian Studies 107, 2013). Designated rules, such as fishing and gathering rules, were put in place and maintained by the Ali'i, the royalty, to protect the sustainability of the various aspects of the system (Williams, R., Hawaiian Studies 107, 2013). It was with a cultural predilection for a great amount of observation, a high level of importance, and the obvious need for sustainability, which the Hawaiians attended to the ever-present demands that humans have for the needs of life (Williams, R., Hawaiian Studies 107, 2013).

One only needs to look at the cases of Rapa Nui, also known as Easter Island, to understand why sustainability is so important to isolated island cultures. According to Bork and Mieth in 2003, Rapa Nui is known as an example of what happens to a self-sustaining island when conservation techniques are not in practice and the island suffers from sustainable collapse. This is what happens to an environment when a series of actions take place that render the land completely devoid of any trees, for this and other reasons, it became incapable of sustaining human life. Bork and Meith went on to suggest that this calamity might have been brought on by a continued lack of sustainable practices, whilst maintaining pursuit of the creation of megalithic structures, and that deforestation may have been a leading cause of what led to the inability for the island of Rapa Nui to provide for the people living there (Bork & Mieth, 2003). Over time, Bork and Meith go on to say, and because of the total deforestation, the eventual effects of multiple starvation periods, rats, and disease, was that the people were forced to eventually abandon their homes, places of cultural and religious value, and their life on the island all together. Research continues on the possibilities for rehabilitation of the island, but success will require new agricultural techniques, in combination with sustainable practices, and a good measure of time, before a significant positive shift can occur (Bork & Mieth, 2003). Other island nations have the unique opportunity to consider the lessons offered by Rapa Nui, and may want to seek sustainable options to provide for their islands' specific needs.

Hawai'i is one of these island nations that could directly benefit from increased sustainability. Hawai'i is also currently in the position to implement some more sustainable practices, as well as use more modern technology, and does not lack for investors to help to achieve this very possible goal, as one can easily see from the multitude of building cranes that now contribute to the Honolulu skyline, that investors are investing in Hawai'i. Interestingly enough, according to the United States Census Bureau as of 2014, Hawai'i imported $5.330 billion dollars of goods into the state that year, which indicates a *slightly* more sustainable downward trend from the $6.662 billion dollars spent on imports in 2012, but also suggests that there is still substantial room for improvement. These import numbers show needs that are present from the lack of availability of locally produced options to fill the demands. Textiles and apparel are among the items on the list of imports and exports for the state, and if Hawai'i could produce what textiles it currently imports, then it might provide enough incentives to perpetuate the situation, which might promote and contribute towards overall sustainability. Hawai'i is ready to become more sustainable again, and there is no better way for me to glorify and honor the islands than through the creation of sustainable products that are locally inspired and locally produced for people who live in Hawai'i *and* visitors alike.

This study explores the possibility that an exclusive sustainable textile industry in Hawai'i could happen with a significant number of people with common goals coming together to create something beneficial for the community. Textile sustainability would be desirable for Hawai'i because through this industry, people who live in Hawai'i may find additional employment opportunities to earn an income more appropriate to the cost of island life. Page six of the

Industrial Hemp Study done in Hawai'i by the ADC in 1997, claims that there have been lands and workers in, “dire need of new employment,” since the sugar cropping came to an end. These lands could be used to grow viable crops with high product yield, such as hemp or kenaf, and with the quick crop growth, farmers would have plenty of work (Hemp Technologies, 2008). At present, Hawai'i is poised to make garments from these textiles that would be exclusive to Hawai’i, due to the garment manufacturing industry already having a significant history and a strong voice in the story of modern Hawai'i since ‘contact’ (Arthur, 2000; Chinen, 1986; Fundaburk, 1965). Now, with the strong current consumer push towards product sustainability, which was not as present or demanding in years before, a local fashion industry supported by a local sustainable textile industry would go a long way towards contributing to Hawaiian sustainability and towards meeting other sustainable goals into the future.

The following sources have all expressed that sustainable and more socially responsible fashion is recently more important because of the large wake of residual damage has been, and is still regularly instigated, by the creation and mass production of fashion items that are still, and have previously been, produced with little or no regard for environmental health, social health, or psychological damage caused to these facets of human existence (Karthik et al., 2015; Kunz & Garner, 2011; Tortora & Eubank, 2010). Long term damage to our planet is occurring because of the general acceptance and mass pursuit of what amount to destructive practices that address human vanity in the form of ‘fast fashion,’ and Karthik et al. (2015) conjecture that very few options, for the production of fashion or luxury goods that do not violate the integrity of our existence, are available for modern designers that have committed themselves, and their designs, to bringing about a change of the psychology of the consumer in such a way that; fast fashion is no longer what is desired, but rather, longevity of personal fashion; quality garments that present themselves to consumers as smart, individualistic, beautiful, sustainable, and transcendent of momentary fads. Textile sustainability would help to provide for some of these options. In pursuit of this vision, the following objectives are goals to reach on the path of undertaking this substantial task.

Objectives:

Four research objectives have solidified to help direct this research.

1. Identify raw fiber possibilities in Hawai'i.

2. Asses strengths and weaknesses of select kapa textile by performing five ASTM standardized textile tests.

3. Catalogue examples of other Hawaiian grown raw materials that are made into luxury products by local businesses that operate with actions towards sustainability.

4. Present Wear on Earth - Hawai'i as an example of a local business that wants to use sustainable fashion to contribute to increased sustainability for Hawai'i.

Chapter One: Objective 1: Hawai'i's Natural Resources

The gradual awareness about the finite amount of natural resources has slowly been changing the way society perceives and values these resources, which helps to usher in a new global cultural understanding, that sustainability and conservation of our treasured limited resources is a must (Karthik et al., 2015). Several possibilities of locally occurring raw fibers are already available to create the local textiles that have existed already in Hawai'i. New fiber resources are being tested for ability to be grown in Hawai'i, but these materials could be made more widely available for a luxury textile industry use. For the organic possibilities, several plant species are already present in Hawai'i but are currently being under-utilized; such as *Gossypium sanvicense or* Ma'o, which is Hawaiian cotton, *Broussonetia papyrifera,* known as the paper mulberry tree, wauke, or kapa; *Hibiscus cannabinus*, also known as kenaf; *Pandanus odoratissimus,* or *Pandanus tectorius* which are known as Lauhala or screw pine; and *Ananas comosus* which is pineapple. A good candidate that legally only exists in Hawai'i in the current feasibility study, is *Cannabis sativa* or industrial hemp, however, this excellent fiber source may offer the best possibility amidst the current evolving social climate to be the primary contributor to the kind of exclusive market that will more than likely be necessary to support the sustainable fashion industry. Luxury markets include products that are not considered crucial for existence and usually reflect an increase in cost due to product materials, quality, rarity, demand, and now the ability to offer positive legacy as a feature of the product.

Cotton:

The Ma'o, or cotton, I recently saw growing on the side of the road with no obvious care produced a cotton fiber that is approximately 22mm long, and white see figure 1.1. Little to no fertilization of the Ma'o plant is required after the shrub has a chance to establish itself, showing the self-sustainable nature of the plant (University of Hawaii, 2009). Cotton has been grown in Hawai'i, on Maui and on the Big Island of Hawai'i, since the early to mid-eighteen-hundreds since the Governor Kuakini opened a cotton plant in Kailua, and continues to be grown to this day, but still has yet to be used as an vital economic supplement (From Seed to Yarn, 2015; Hawaiian Native Plant Propagation Database, 2001; Langton, 1904; Rauch et al., 1997; Sakovich, 2013). In well drained coastal soils, and in the fullness of tropical sun, Hawaiian cotton can withstand, and thrive, the adverse tropical crop conditions of increased salinity of the soil, frequent drought, heavy winds day (Rauch et al., 1997; University of Hawaii, 2009).

Figure 1.1 shows one cotton seed and fibers brushed out from a sample that was taken of cotton growing on the side of the road in Waimanalo.

Hawaiian cotton is known to be a plant that is vulnerable to becoming an endangered plant species, however if there is any way to revive this plant as a viable textile fiber to be commercially grown again in Hawai'i, then there is a chance that it may be able to recover from its vulnerable status (Hawaiian Native Plant Propagation Database, 2001; Rauch et al., 1997; Sakovich, 2013; University of Hawaii, 2009, USDA, 2006). Growing on coastal planes, cotton has previously done well in in the Hawaiian Islands and has grown successfully on most of them even though it presently does not grow on Kaua’i in the wild or on the Big Island (Hawaiian Native Plant Propagation Database, 2001; Rauch et al., 1997).

This remarkable plant is capable or propagation by a variety of means such as seed, cutting, and air layering, which should ease in the recovery of this species in the future if cultivation and species restoration are to occur (Hawaiian Native Plant Propagation Database, 2001). In some places it is grown annually, but in the tropics, it can be cultivated to year round production and individual plants may last as long as five years if conditions are right day (Rauch et al., 1997; University of Hawaii, 2009). It is fair to say that the uses for cotton are well and widely known, however the same uses were not applied to cotton in Hawai'i, as the woven forms of the fiber were not widely used until importation of the cotton textile became the norm (Arthur, 2000; Chinen, 1986; Fundaburk, 1965; Hawaiian Native Plant Propagation Database, 2001). Economically speaking, cotton is much more affordable in Hawai'i if imported from China or India, however, the possibility for growing cotton in Hawai'i as a viably economic crop would be contingent on the demand for these sustainable and locally produced items and the willingness for the consumer to pay the increased cost for the production of said products.

Kapa:

Even though *Broussonetia papyrifera* is known in some parts around the planet as being an invasive weed, it is a highly valued plant in Hawaiian culture; see figure 1.2 (Floras of North America, 1799; Morgan & Overholt, 2004). It is native to East Asia, and has been used for paper there, but due to its ability to survive in various climates, and its usefulness to certain cultures, it has established itself on several continents and continues to spread (Floras of North America, 1799; Morgan & Overholt, 2004; Taylor, 2011). In Hawai'i it is also called a canoe plant because it is thought to have been brought on the canoes with the early Polynesian settlers, and is the predominant plant that provided the Hawaiians with the cloth they needed for the multiple uses in their lives (White, 1996). Hawaiians tended to keep the trees to a manageable height of about eight to twelve feet for the purpose of producing kapa cloth which was valued for its quality, durability, hand, and resistance to pests and water (Floras of North America, 1799; Morgan & Overholt, 2004; Taylor, 2011; White, 1996). The *Broussonetia papyferia,* also called the paper mulberry, tends to naturally grow in dense clumps that are formed by the growth that occurs at the roots, spreading outward to upwards of thirty feet across, but the plant can also spread long distances by means of seeds (Morgan & Overholt, 2004; Taylor, 2011). The plant fibers are on average about 10 mm long, ranging from 6mm to 20mm, and have a width of about 30µm (Taylor, 2011) .

Figure 1.2 shows a paper mulberry plant. Retrieved from http://www.canoeplants.com/index.html

Kapa, which has been known to function as clothing and as currency, gets its Hawaiian name from being beaten (Francis 1997). If there had not been a few individuals that maintained the art-form and passed that knowledge on to younger generations, it might have been lost, completely forgotten (Francis 1997). Fortunately for Hawai'i, kapa artisans are still growing, harvesting, and making kapa today and they are making it the same way that they have been for millennia, but they are making it with new and exciting applications and products in mind that might bridge the gap between ancient art form and modern luxury.

As a cultural textile, kapa may need to be limited in sales to the ultra-exclusive textile conservatories in Hawai'i as a fine art textile product; however the fibrous properties of the plant might be possible as a textile fiber for commercial woven applications as well, although further in-depth research would need to be conducted on this subject involving the cropping, harvesting, spinning, and weaving of this fiber, as well as performing some of the standard textile tests from the American Association of Textile Chemists and Colorists (AATCC) and the American Society for Testing and Materials (ASTM) (ASTM, 2004; Taylor, 2011).

Hawai'i is rich in renewable resources that could help to provide for many sustainable industries or businesses. In the case of textile industry and fashion industry in Hawai'i, both of these industries would be able to support each other, and then by their very nature, support the community as well. To support the Hawaiian textile community, some standardized ASTM textile tests were performed on kapa textile, in an effort to provide important data that is pertinent to the potential use of kapa in a more modern setting and to assess its strengths and weaknesses for a broader range of end use applications.

Kenaf:

From all accounts it appears that kenaf, *Hibiscus cannabinus*, could be another raw material that supports Hawaiian textile sustainability. Uses are being re-engineered for this plants' components that are akin to those uses of *Cannabis sativa* such as: textiles and clothing, paper, construction particle boards, polypropylene composite, automobile, environmental remediation, geotextile, and livestock applications (Brazil Kenaf Project, 2005; Edeerozey, Akil, Azhar, & Ariffin, 2006; Kenaf Plant 2010; Yu & Yu, 2007).

It has been cultivated around the world for thousands of years and used predominantly for its fiber although the plant's leaves have been consumed by both man and beast, and the seeds have proven to be useful to humans in a nutritional capacity as well as industrial (Kenaf Plant 2010, Webber & Bledsoe, 2002; Edeerozey, et al, 2006). It takes about 200 days for the plant to reach maturity, or about 15 feet tall, and produce the fibers for which it is partially cultivated (Brazil Kenaf Project, 2005; Webber & Bledsoe, 2002). It has two layers of bast fibers that can make up to 35% of the plant when dry, and when grown in tropical regions that offer ideal conditions, such as Hawai'i, full plant yield per acre can be up to fifteen tons (Brazil Kenaf Project, 2005). The fibers from the bast can be up to five millimeters long and an average of about 20μm wide, and there is research in to their use in textiles (Iii, Akin, Archibald, Dodd, & Raymer, 1999; Webber & Bledsoe, 2002).

Kenaf, *Hibiscus cannabinus*, can provide a multitude of useful components similar to what hemp provides. Kenaf can produce greater yields when planted in higher density of up to 370,000 plants per hectare which reduces branching within the population, and can also be processed by similar decortication and retting methods as hemp to acquire the fiber from the plant see figure 1.3 (Brazil Kenaf Project, 2005; Webber & Bledsoe, 2002; Yu & Yu, 2007).

Figure 1.3 Kenaf bark fiber strands; fiber strands after harvesting with a forage chopper (left), retted combed fiber strands (center), and fiber strands compressed into a square cube. Retrieved September 13, 2015, from http://www.hort.purdue.edu/newcrop/ncnu02/v5-348.html

Also of note, are the plants attributes towards usefulness for environmental clean-up through retention and remediation of soil, toxic waste clean-up, and its ability to contribute to eco-conservation because of reduced energy need and reduced chemical use for processing; all of which contribute to the plants feasibility for use in Hawai'i's exclusive and sustainable local textile industry (Kenaf Plant 2010; Webber & Bledsoe, 2002). All of these positive attributes are somewhat paled in comparison to hemp, however, if it were not possible to grow hemp, kenaf would be a good possibility in its stead.

Lauhala:

Due to the production process, lauhala textiles, which come from the *Pandanus tectorius,* also known as screw-pine may also experience sales that predominantly occur in the ultra-exclusive textile conservatories as another possible source of Hawai'i's cultural textile products capable of contributing to local textile sustainability and the fashion industry. It is similar to kapa in demonstrating a human heavy process and also requires a high level of craftsmanship for the textiles to come into being. Other parts of the plant have a diversity of uses, but it is the leaves that are used for traditional weaving of lauhala textiles see figure 1.4 (Thomson, Engelberger, Guarino, Thamen, & Elevitch, 2006).

Figure 1.4 Woman weaving Laulala Retrieved from www.traditionaltree.org

Lauhala is different from the other raw textile sources because it is not the fiber that is being used, but rather entire sections of the leaf that have been cured and processed that are woven and plaited into various useful and aesthetically pleasing artifacts, to add convenience to life, and as a display of identity and wealth **(**Thomson et al 2006).   Different kinds of mats bearing intricate designs have been woven using a variety of strip sizes and have different purposes from floor use to ceremonial apparel that is worn at the waist (Thomson et al 2006)**.**

Because of the cultural exclusivity and rarity of Lauhala textiles and creations, the products that are produced by the local artisans, and that do become available to the general population, could be valued with a similar ruler as one would use for modern ethnic art. It has been reported by Tongans that there is enough demand for their lauhala products to keep the price fairly stable, and with the push towards sustainability and cultural interest that humanity appears to be making now, placing greater value on items of local make, there just might be a significant place for lauhala at the Hawaiian sustainable textile table after all (Thomson et al 2006).

The cost of this as a prepared raw material has increased tremendously, lending to the probability of perceived value, and to try to combat that, technology has been investigated for the purpose of reducing the prepared per-leaf cost of the *Pandanus* so that local weavers could afford their supplies. As can be the case with most art supplies, the high cost of quality materials is often the barrier to fine art production (Kirschbaum, 1953; Thomson et al 2006). However, with the higher prices they could earn for their products with the use of a different marketing approach by treating woven lauhala products as fine art instead of trinkets, combined with the lowered cost of the product materials, there could be a possibility that the traditions of lauhala weaving could gain interest amongst the weavers again see figure 1.5 (Thomson et al 2006).

Figure 1.5 Fashionable Lauhala bag.

Even though the fiber is not being currently used in a yarn to woven textile capacity, research has been conducted to investigate the mechanical properties of screw pine fibers (Abral, Andriyanto, Samera, Sapuan, & Ishak, 2012; Thomson et al 2006). These fibers, which Abral et al 2012, said in their article titled, Mechanical Properties of Screw Pine (Pandanus odoratissimus) Fibers – Unsaturated Polyester Composites, looked like straight hair, and were removed from the leaf by way of boiling and rinsing, and were dried, before being subject to various tests such as moisture absorption, tensile, and flexure testing. ASTM and AATCC tests on textile produced from *pandanus* yarn would be the best indicators as to if or not the fibers in this plant might also have broader commercial textile applications.

Pineapple Leaf Fiber (PALF):

For communities or industries that are agriculturally based, agro-waste, as a source for viable materials to support other industries, is proving to be a successful addition to the economic incentives for searching out sustainable options for total product use (Mishra, Mohanty, Drzal, Misra, & Hinrichsen, 2004). In the case of pineapple, *Ananas comosus,* and Hawai'i, which has been cultivating the Smooth Cayenne pineapple for Dole as a food product, the Pineapple Leaf Fiber (PALF) may prove to be an agro-waste resource that could contribute to a luxury textile industry in Hawai'i that helps to support the sustainable fashion industry (Mishra et al., 2004; Rhodes 2013; Sapuan & Abdan, 2009).

The strong and silky PALF has been used for textiles and textile applications by various cultures since the 1500's, and since it is one of the most significant fruits in Malaysia, new research is being conducted there on the other industrial and commercial applications including as use for textile production (Morton 1987; Sapuan & Abdan, 2009). A variety of textiles can be produced from this PALF yarn which can lead to new apparel uses (Doraiswamy, & Chellamani, 1993). Cross-sections of leaves from three different cultivars, the Moris Gajah, Sarawak, and the Josaphine, see figure 1.6, revealed large fiber bundles that were between 100-

600μm in diameter and technical fibers, which ranged from 30 to 80μm across, and elementary fibers that had a diameter that was often under 10μm, (Sapuan & Abdan, 2009). It is worth pointing out that these fibers do not need additional technology to be spun into Piña cloth, as they are able to be spun on machines that spin cotton as well as on machines that spin jute (Doraiswamy, & Chellamani, 1993).

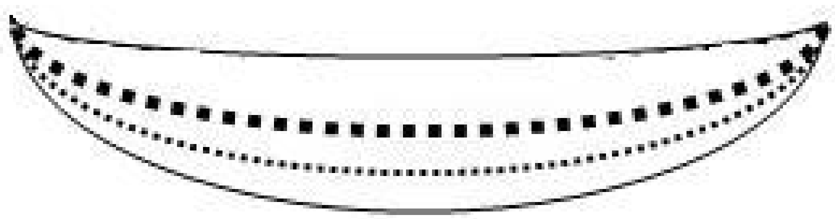


Figure 1.6 Shows growth patterns of pineapple leaf fiber bundles. Retrieved from http://www.researchgate.net/profile/S_Sapuan/publication/267726609_Characterization_of_pineapple_leaf_fibers_from_selected_Malaysian_cultivars/links/5486df2b0cf2ef34478ce2d5.pdf

It is the longest leaves of the *Ananas comosus* that are the best for fiber use and must be decorticated and ret to release the fibers. There are various processes in use for retting, but much like that of other fibers that need retting, new technology is becoming available and is being tested to decrease retting time, and increase not only the sustainability of fiber production, but fiber performance factors as well (Morton 1987; Sapuan & Abdan, 2009). However, for mechanical decortication, no new machinery is required as the ones that are already in use for sisal are compatible for pineapple leaf fiber as well (Morton 1987; Sapuan & Abdan, 2009). It has been estimated that about 60 pounds of fiber can be removed from approximately one ton of leaves (Morton 1987). At 400 million pineapples a year in Hawaiian production, that is quite a bit of fiber that goes to agro-waste if the leaves are discarded as trash. Hawai'i could reclaim this agro-waste and can add significant value to it by spinning it into Piña cloth for the local designers (Rhodes 2013).

Hemp:

Even though *Cannabis sativa* has a long and rich history with the United States, enjoying legality and some level of prestige as a highly versatile plant capable of quality products, it is a species of plant that was banned for a number of years in Hawai'i. It is also a species of plant that contains many cultivars capable of producing a broad array of characteristics that each cultivar can be bread specifically to produce. These characteristic differences in the cultivars range from providing medicinal values, to many industrial applications, such as textiles, building materials, and chemical feedstock, and can provide food, energy, and recreation for the society that chooses to farm this crop, see figure 1.7 (*Hemp Technologies, 2008; USDA, 2000;* Yonavjak, 2013). There is, however, a current feasibility study being conducted in 2015 that will be presented within a few months of this paper's completion to assist the Hawaiian legislature in their decision regarding a new vote that is scheduled to occur on this issue.

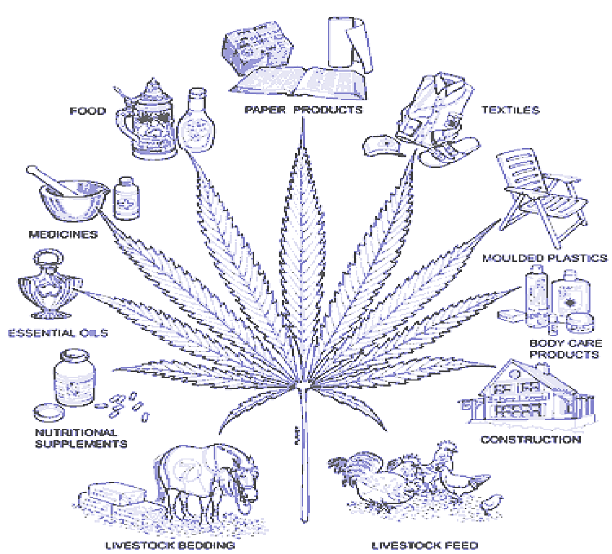


Figure 1.7 is a diagram showing the many uses of hemp. Retrieved from https://hort.purdue.edu/newcrop/ncnu02/v5-284.html

Some *Cannabis sativa* varieties that have been cultivated specifically for the fiber market have been known to produce up to 50% fiber bark, and up to half of that bast fiber had the possibility of being primary fibers, which are the most desirable, see figure 1.8 (Small & Marcus, 2015; Turunen & Van der Werf, 2006;). These specific cultivars could be further developed to supply the needs of, in this case, the Hawaiian market (Hemp Technologies, 2008). Although other parts of the plant are capable of being used for a variety of purposes, the bast fibers, which grow beneath the epidermis in the layer known as the phloem, are what are necessary for textile production (Turunen & Van der Werf, 2006; USDA, 2000). In the layer between the cortex and the cambium is where the primary and secondary bast fibers grow vary in length and in amount of lignin they contain (Liu et al, 2015*;* Turunen & Van der Werf, 2006; USDA, 2000).

Figure 1.8 shows the differences in hurd and fiber content between cultivars. Retrieved from https://hort.purdue.edu/newcrop/ncnu02/v5-284.html

The two different kinds of bast fibers in hemp that are found in the phloem tissues are, the primary fibers, which can range from 5mm to an amazing 100 mm long, which is partially why the plant is so useful, and secondary fibers, which are closer to the 2mm range in size, see figure 1.9 (Liu et al, 2015*;* Small & Marcus, 2015; Turunen & Van der Werf, 2006;).

These fibers occur in long bundles of up to five meters long and are amalgamated by the lignin and pectin cement (Liu et al, 2015*;* Small & Marcus, 2015). Hemp can be planted in high density formats; and the combination of its strength when dry or wet, with its natural resistance to spoilage, make its durability as a fiber very useful and desirable for many industrial uses, See figure 1.10 (Small & Marcus, 2015; Turunen & Van der Werf, 2006).

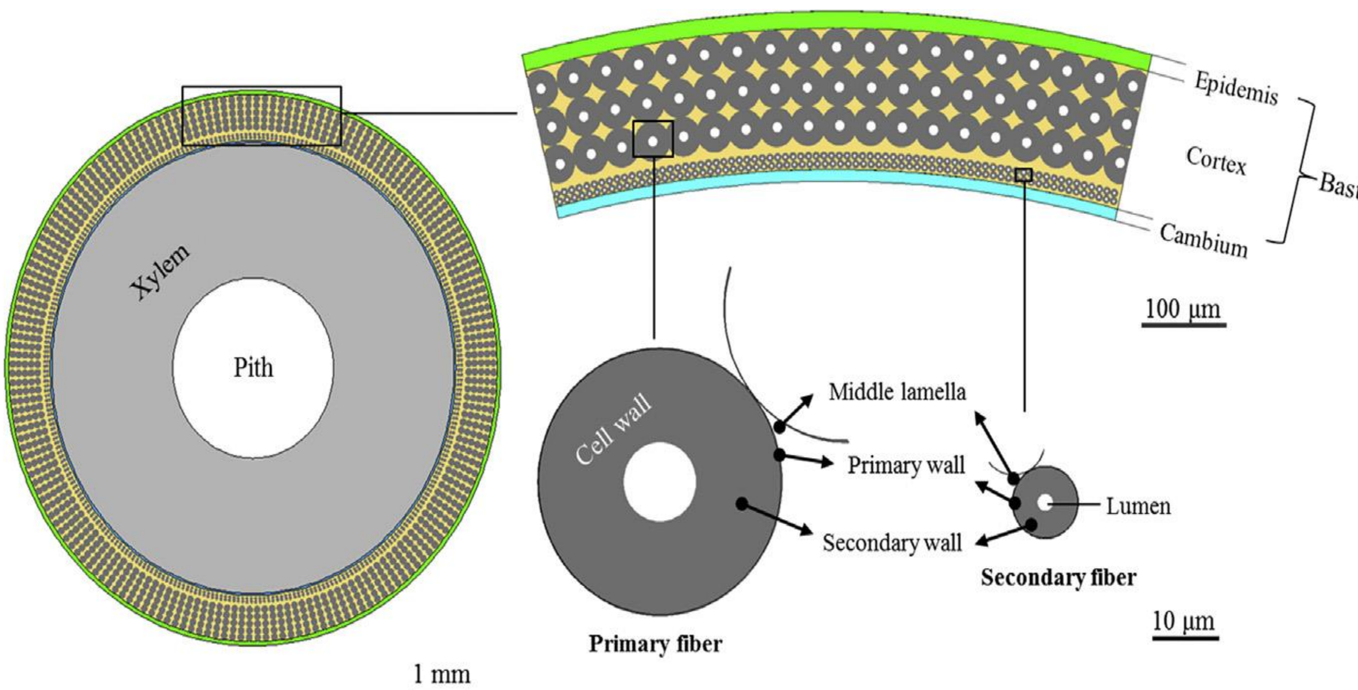


Figure 1.9 Shows growth patterns of hemp bast fiber bundles. Retrieved from http://ac.els-cdn.com/S0926669015001053/1-s2.0-S0926669015001053-main.pdf?_tid=eb41bfa4-5717-11e5-86db-00000aacb362&acdnat=1441819774_1b6436c425e7039605cd1166e5447d37

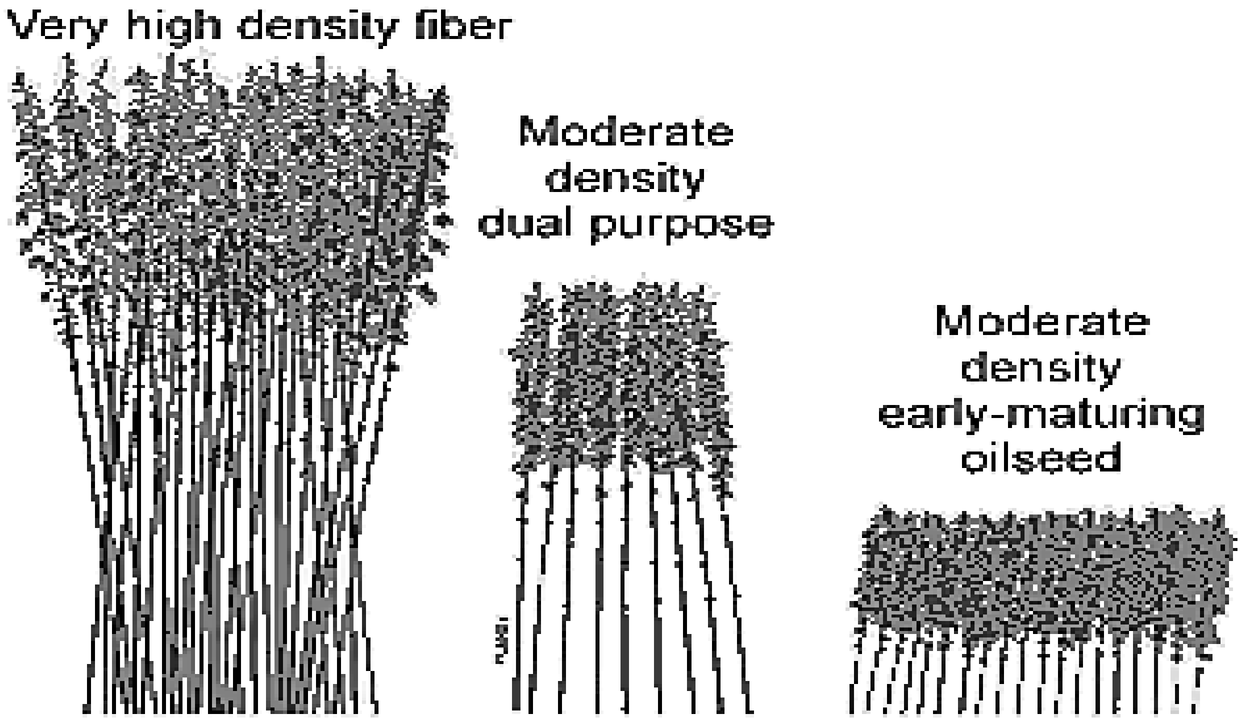


Figure 1.10 illustrates an example of density planting. Retrieved from https://hort.purdue.edu/newcrop/ncnu02/v5-284.html

Chapter Two: Why choose hemp and can it grow in Hawai'i?

There is an additional focus on hemp as it relates to Hawai'i because through a current feasibility study, hemp may have proven that has the capacity to be a significant fiber provider for the local textile industry. The source for information regarding the current feasibility study of industrial hemp production in Hawaii comes from Dr. Harry Ako who is overseeing the study, in which field and laboratory research is currently being conducted through the Department of Molecular Biosciences and Bioengineering at the College of Tropical Agriculture and Human Resources at the University of Hawai'i at Mānoa, CTAHR. The current study is researching the growing behavior and needs of *cannabis sativa* in Hawaii in the hopes of finding industrial cultivars that can be grown successfully with the particular Hawaiian conditions; however this thesis is only concerned with CHG, the fiber cultivar being tested, and according to Ako, there is a species of hemp that can successfully grow in Hawai'i see figure 2.0. One must see the completed study for further data; it is in progress and has not published at this time so information is therefore limited to what has been allowed by Ako. This study is currently entitled, *Growing Industrial Hemp (Cannabis sativa) in Hawai'i: A Feasibility Study*, and is by Harry Ako, Melody Heidel, Alan Yoshimoto, Mashihiro Yoshioka, and Jennifer Bright.

Figure 2.1 shows hemp growing in Hawai'i.

According to the USDA in 2000 in their study called the *Feasibility of Industrial Hemp Production in the United States Pacific Islands*, fiber yields are documented at a relatively low percentage yield, providing approximately 1,600 pounds of dry retted fiber per acre on a total one acre full-plant harvest of just over 35.5 thousand pounds of plant matter; indicating that although the yield of about 4.5% fiber per crop harvest seems small in actuality, it leaves the rest of the other viable parts of the plant available for other applications, and there is the possibility due to the change in the times and social and environmental awareness, that this small physical yield could provide for a larger percentage of the actual economic yield in terms of money being exchanged for this particular commodity.

Directly related to the amount of fiber the plant can produce is the amount of sunlight it gets and the time of harvest (Liu et al, 2015). In their article, Effect of harvest time and field retting duration on the chemical composition, morphology and mechanical properties of hemp fibers, Liu et al, (2015), discovered that the more light the plant gets on all sides, the bigger the plant can grow, and the more fiber it will be able to produce, but with the onset of plant maturity, as described as the beginning of flowering, the bast is mature and ready for harvest, but with the continued ripening of the plant into seed stage, the actual thickness of the primary and secondary fibers decreases.

Assuming that legalization will occur, the private sector will undoubtedly get involved and the truth of probable profitable applications due to the multi-faceted nature of this plant will have the possibility of being expanded on in ways that have not even been considered yet. Hemp is quick to mature in relation to some other industrially purposed crops, even in relation to kenaf, offering a chance for greater crop return per acre per year for farmers,' and greater overall economic savings and return to Hawai'i from sales of in house products; which suggests that the hypothesis may be supported (Hemp Technologies, 2008; USDA, 2000; Yonavjak, 2013).

From all the research about the raw materials that exist in Hawai'i and could be cultivated in a sustainable manner to provide the fibers necessary for the creation of exclusive and local Hawaiian textile industry, it appears that these Hawaiian Islands *are* physically capable of providing for a local and textile industry. The tricky part is going to be in maintaining the sustainability, but if all the lands that have been listed as available and in need of crops, begin to be used for the purposes of providing for this industry in ways that are consistent with sustainable and responsible practices, it could be attained in the near future**.**

Chapter 3: Hemp Fibers to Textiles in Hawai'i

Previous research done by the Agribusiness Development Corporation in 1997 showed that it was cost previously prohibitive to consider the possibilities of textile production here in Hawai'i, however, as a result of the positively changing mentality towards industrial hemp and sustainability in general and the preliminary data coming from the feasibility study happening in Hawai'i, the possibilities of exclusive textile production in Hawai'i seem to have increased significantly.

Moving from a raw material to premium textiles is a somewhat complex, but totally possible series of events. Of course, growing and harvesting quality cultivars of fiber rich hemp is the first major and critical step in the production of hemp textiles, but once that has been done; the processing towards textile can begin. Modern technology as created a machine called the decorticator that can do the work of removing the fiber from the plant by breaking the hurd, and scutching or separating the fiber from the mass (Small & Marcus, 2015; Turunen & Van der Werf, 2006). Hobson, Hepworth, and Bruce (2001) remark that this machine produces whole fiber which would be good to use for textiles and can decorticate hemp stalks that have already been retted or ones that are unretted see figure 3.1. Even though the longer thinner fibers are the most desired for spinning into premium textiles, sometimes the fibers are separated and broken down into much smaller sized staple fibers, similar to cotton which is called 'cottonizing,' for the purpose of working the hemp fibers through machines that are not initially meant to spin hemp fibers (Liu et al, 2015; Small & Marcus, 2015; Turunen & Van der Werf, 2006).

Figure 3.1 illustrates the decorticator processing bast fiber stalks. Retrieved from (Hobson, Hepworth, & Bruce, 2001). http://ac.els-cdn.com/S0021863400906310/1-s2.0-S0021863400906310-main.pdf?_tid=fdce99dc-5382-11e5-aa2e-00000aab0f01&acdnat=1441425957_396a5e60d174979d57511b8dd197e02f

Dew retting and water retting are still major ways that the fiber is removed from the plant (Small & Marcus, 2015). Dew retting, or field retting, happens when the cut plant is left in the field for two to three weeks and are predominantly attacked by fungus which produce enzymes that begin to decompose the pectin and lignin portions of the plant, which releases the fibers from their bundles, see figure 3.2 (Liu, Fernando, & Daniel et al, 2015; Small & Marcus, 2015). It is a cost effective and environmentally beneficial way to gain access to the fibers used for other applications, to maintain a greater overall consistency of fiber properties, but also allowing for timely rotation of other crops (Liu et al, 2015). In some locations it could be somewhat limited in terms of reliability of consistency, simply because the success of this method is determined on the environmental conditions necessary to best perform this retting process in the least amount of time, but if these needs are met, Nebel (1995), suggests that this is a good method for quality fiber pre-production. Hawai'i is uniquely suited for this field retting due to the moist tropical environment that promotes quick decay to release the available nutrients back into the soil.

Figure 3.2 Illustrates hemp retting in the field.

Because of increased pollution from water retting, which traditionally happened in ditches or in open water sources, it can now be conducted in specialized tanks used for this purpose. Retting is important to hemp textiles; especially wet retting, because the thinnest highest quality fibers are only achieved through this process. Wet retting can also improve the process of steam explosion, which continued research has shown since 1995 to have the potential of producing a hemp fiber quality that rivals superior cotton, but without the level of water pollution that wet retting causes (Liu et al, 2015; Nebel, 1995; Small & Marcus, 2015).

Steam explosion is an alternative method for extraction of the fibers, which separates the fibers through a process involving high pressure, temperature, steam, and occasionally additives, and might redefine the best methods for hemp fiber extraction in the future (Liu et al, 2015; Nebel, 1995; Small & Marcus, 2015; Turunen & Van der Werf, 2006. Steam explosion offers the possibility of customizing the fibers needed to produce particular effects, producing new types of yarns in the process, and resulting in new weaves and product potential (Nebel, 1995). This new technology that Nebel mentions has more than likely been developing since the 1930's through the rising surge of the 'green' and 'hemp' movements that have been building side by side and instigating technological advances in those arenas. There has been a need to reduce the hemp fiber's fineness to that of cotton or wool such that it can enter the luxury textile market through processing on machines that spin cotton into yarn, and through steam explosion, a customized fiber for a variety of desired luxury end uses can finally be realized through this process (Nebel, 1995). A higher quality fiber, continues Nebel, requiring less processing with chemicals for production, mostly steam, and that generates a biologically degradable waste water, which is filled with other agro-waste possibilities in the form of lignin and pectin, can be offered as a superior and environmentally friendly option to cotton.

Large areas and warehouses dedicated to the manufacture of hemp yarn and textiles would need to be available, as the machines to spin yarn and weave cloth are large, however the process has become quite advanced, and the machines are much smaller now than previous versions, have become more sophisticated, and the whole process has become according to Clifford (2013), much more clean, safe, and technically advanced, see figures 3.3 and 3.4.

Figure 3.3 illustrates a modern yarn spinning factory. Retrieved from Mars Enterprise,s 2014. Mars Enterprises-Textile Manufacturing. http://www.marsenterpriseshkltd.com/Textile.htm

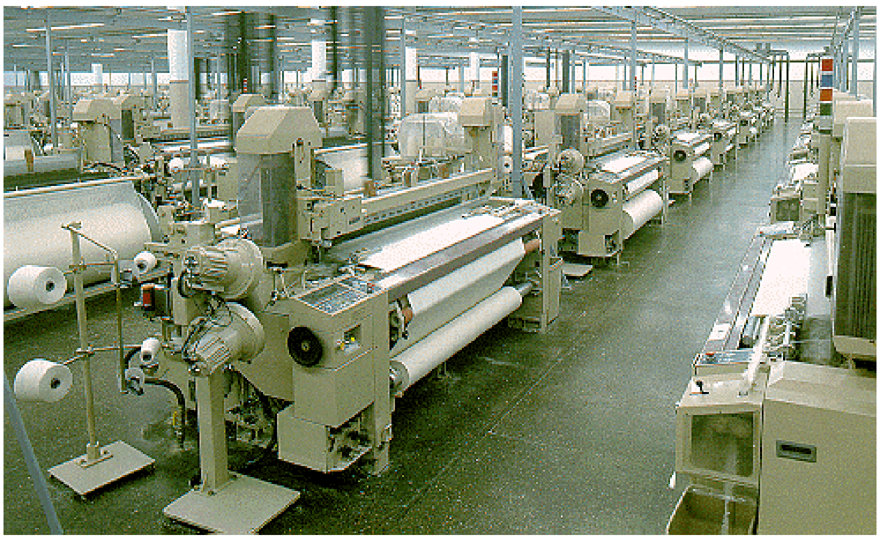


Figure 3.4 illustrates a modern textile weaving factory. Retrieved from Warshaw, L. (1996). Chapter 89 -Textile Goods Industry. http://www.ilocis.org/documents/chpt89e.htm

It appears that as a result of America choosing not to grow hemp for a variety of politically motivated reasons, that other countries and unions, such as China and the European Union, became better prepared to begin their hemp textile industries, but the new rise in desire for sustainability and products that have meaning and memories associated with them may just prove beneficial for select locations to plant their seeds, literally (Small & Marcus, 2015; Turunen & Van der Werf, 2006). Hawaii is one of those places where all of the elements that are important seem to line up: location, feasibility, accessibility to lands, employment opportunity/need, and environmental ability and concerns, all coincide with a special time in civilization where it is evolving and collectively choosing to support a movement that itself should sustain into the future. As a result of these things, and the special place that Hawai'i seems to be recognized as in the world, it is the perfect combination of factors to support and compliment a sustainable textile industry with hemp as its most notable contributor.

Small and Marcus continue to suggest, and Turunen and Van der Werf also imply that because of the new developments by the EU, technology addressing the issues related to the harvest and production of these fiber products is moving forward, and because of the new social movement regarding the other useful aspects of the *Cannabis sativa* plant, increased interest in the possibilities and potential of hemp products have drawn out the investors, which cyclically increases technological advances to the field. With this more available and affordable technology, so then becomes more available and affordable the possibility of producing exceptional hemp textile creations in Hawai'i, which could then be used by high end designers and sold by exclusive boutiques who are interested in using hemp and local textiles to promote sustainability with their efforts (Ghadimi, et al., 2013; Hemp Technologies, 2008; USDA, 2000; Yonavjak, 2013). The next chapter will reflect on how unique and particularly Hawaiian garb, and the global interest in it, simultaneously developed, and will present a case by visitor numbers for the restoration and perpetuation of the garment manufacturing in Hawai'i.

Chapter 4: From Textiles to Garments

Several distinct periods are known to classify Hawai'i's industry concerning garment manufacturing and can be succinctly summed up in succession; Preindustrial, Transition, War and Post-War, Rapid Growth, and Chinen (1986) recalls in her working paper titled, The Historical Development of the Garment Industry in Hawai'i, that a period of Deindustrialization occurred starting in 1975, and Arthur (2000) and Fundaburk (1965) both suggest that the entire garment industry in Hawaii saw its beginnings, rise, and decline between 1922 and 1986.

In Chapter three of Aloha Attire, Arthur (2000) indicates that kapa cloth, which was one of the predominant textiles made on the islands for various Hawaiian uses, became increasingly rarer as the availability of woven textiles increased. Supported by Neich and Pendergrast (1997) and Tanahy (2012), Arthur continues to present that Hawaiian sewers and the garment manufacturing industry turned to imported woven cloth, such as cotton broadcloth and silks of various weaves from Asia and Japan, Europe, and the United States to create attire to suit their needs, and eventually the needs of the export and tourist market. In more recent observation, it appears as though specialty textiles with cultural significance could be enjoying a renaissance of sorts, and has appeared in some unusual modern forms in keeping with the evolution of textiles post-contact (Arthur, 2000; Oka, 2015; Neich & Pendergrast, 1997; Tanahy, 2012).

There is a precedent of textile production actually occurring in Hawai'i in 1837; as John Adams Kuakini, the governor of the Big Island at the time, and also cousin to King Kamehameha I, who might have been the only textile manufacturer in Hawai'i, was able to find some measure of success for about three years (Arthur, 2000; From Seed to Yarn, 2015). Kuakini was able to produce cotton textiles of various weave structures including plain, twill, striped and plaid, and had ordered more state-of-the-art equipment, before the inevitabilities of war, politics, and social mentality of the time forced him to close his textile factory in 1840 (From Seed to Yarn, 2015).

Another Hawaiian textile fiber or plant, that has survived and made it into the mainstream and into high fashion, is lauhala (Arthur, 2000). Lauhala is a plant that has long leaves that can be cured and processed before being cut into strips of just about any size before being plaited and or woven into useful and beautiful *shapes* (Hensley & Stibbe, 1997; Stall, 1953). Also known as the screw-pine, Pandannus odoratissimus is known to be indigenous to Hawai'i and has been used for centuries to create long lasting textiles, baskets, hats known as papale, canoe sails, and many other useful items (Hensley & Stibbe, 1997; Oka, 2015; Stall, 1953). Stall (1953) has noted that some burial caves of the ancient Hawaiian chiefs have revealed lauhala mats that were highly valued and enclosed with the chief among his other possessions that were prized above others, (Stall, 1953). Much to the thanks of one of Hawai'i's premiere designers Elsie Krass, who started to dress up the work hats and began pairing them with more fashionable garb in the early 1930s, authentic lauhala hats crafted by the local weavers became a fashionable commodity and the small lauhala industry experienced a resurgence with a new demand for products by the military personnel and tourist populations (Arthur, 2000; Hensley & Stibbe, 1997; Stall, 1953; Oka, 2015).

Due to such influences as the work requirements on major plantations and the demands of an ever-growing U.S. military presence leading up to World War II, recounts Arthur (2000), ready-made clothing was already being imported into Hawai'i by retail stores the early twentieth century to satisfy this need for work clothes, and so clothing manufacture in Hawai'i began its transition from occurring predominantly in home, to full factory manufacturing with the opening of The Union Supply Company and the Hawai'i Clothing Manufacturing Company in 1922; both of which focused production on work clothing used on the plantation and on military garb.

It wasn't until 1936 that the production of Hawaiian styled apparel was happening on a mass scale in Hawai'i through manufacturing companies such as Kamehameha and Kahala, however, Arthur (2000) reported that, the bulk sales of garments that were designed and manufactured in Hawai'i from cloth that had been printed in California, were occurring in places other than Hawai'i, and this was because the locals were still displaying more conservative tendencies towards wearing this 'culturally' inspired dress and did not yet wear some of the more boldly printed 'Hawaiian' garments that were beginning to gain in popularity on the mainland and elsewhere. Even though Arthur (2000) reports in her book, Aloha Attire, that tourism as an industry started in Hawai'i in the 1930's, for the previous thirty years, the Hawai'i Tourist Bureau had already been touting the beauty and novelty of the Hawaiian experience; the inflow of tourists along with the combination of the end of World War II and the influx of multi ethnic population, brought about significant changes in the design motifs used in Hawaiian textiles of the time. Arthur (2000) goes on to imply that worldwide recognition came to Hawai'i during World War II, and with the persistent flow of US servicepersons combined with a new onslaught of tourists, the cut of island garb, along with the exploration of tropical print designs for upholstery garments, Hawaiian apparel had made its global debut.

Now, 75 years after Hawaiian tourism got its jump-start, it has become especially important for sustainability and environmental reasons that members of Hawai'i textile and fashion industries explore the most environmentally beneficial methods of producing these luxury commodities in order to maintain/preserve the quality/integrity of the products as well as the health of the community and environment. Because of the unique global seclusion or intrinsic exclusivity of location, Hawai'i has had the ability to inspire not only the Polynesians who first made it their home and became Hawaiians, but explorers, artists, visionaries, and the world's population in general since its discovery (Williams, R., Hawaiian Studies 107, 2013). It has become a global luxury icon representing tropical island paradise, tropical island culture, and status projected through way of life.

All of this history in combination with the current global trend towards being green is the reason that textile sustainability in Hawai'i is possible now where it was not before; it is because time and situation has changed the mind and hearts of the average consumer such that the concepts of product sustainability and responsibility are far more important factors to consumers' choices today (Ghadimi et al., 2013*)*. The gradual awareness about the finite amount of natural resources has slowly changed the way society perceives and values these resources, which helped to usher in a new global cultural understanding; that sustainability and conservation of our treasured limited resources is a must (Ghadimi et al., 2013; Karthik et al., 2015). It has become fashionable to be environmentally friendly, and in many cases now, it is even frowned upon if one is openly un-environmentally friendly (Kunz & Garner, 2011; Tortora & Eubank, 2010*)*. Because of this newfound "green" awareness, an increased demand for more ecologically, environmentally, and socially responsible behavior in textile and garment production, is backed by a surge of renewed consumer interest in sustainable textiles which has been supporting the new, and continued use, of natural fibers for the creation of responsible textiles for this vast and quickly emerging market (Ghadimi et al., 2013; Karthik et al., 2015; Kunz & Garner, 2011). Due to locational costs and demands, these textiles would not be cheap to produce in Hawai'i; they would more than likely need to be sold with a higher price in luxury market categories in order to perpetuate the industry and achieve some sustainability through the creation of this industry locally.

To create luxury items worthy of the prices they sport, industry standards must come into practice. Regular and luxury use textiles and garments are no different, being tested, measured, burned, torn, wrinkled, bent, abraded, faded, stained and so much more, for the purpose of informing the designer about the capacity of the textile and producing a higher quality product. To the textile industry, these standardized tests are put offered by American Society for Testing and Materials (ASTM), and American Association of Textile Chemists and Colorists (AATCC), in an effort to make available the properties of various textiles in a standardized way such that members of the industry have ways to gauge, rate, and assess infinite kinds of textiles for various end uses. Without these tests, there would be no true quality control and no way to understand or offer product reliability or guarantees.

In the next two chapters, a closer look at hemp fibers and kapa fabric are provided. The experimentation on the hemp fibers granted deeper understanding of the wet retting process. It also provided some interesting results that were both surprising and beautiful, but that may ultimately be useful to the Hawaiian kapa making community.

A more in-depth exploration into the possibilities of kapa was also provided in the form of these standardized tests, because kapa as a cultural textile, has the possibility to be present and in the foreground of the Hawaiian textile scene, and having some data from these tests helps to catapult the cultural textile into the 21st century, and arms the kapa designers of today with some new tools to level the local textile playing field.

Chapter 5: Research results of wet retting hemp in Hawaii

In addition to being provided access to, and helping with collecting research data from the field, further research was performed to assist with the feasibility study as it pertains to the bast fibers located in the plant. The objective was to more fully understand the wet retting process of hemp in natural Hawaiian conditions, see figure 4.1. All hemp stalks used in this research were grown in Hawai'i and provided through legal permitted access relating to the current feasibility study.

Through multiple processes of experimentation and correlational field research, it might be possible to ascertain the potential of using industrial hemp to fill one of the raw material voids as a primary fiber for the sustainable textile industry that is so badly needed in Hawai'i (Agribusiness Development Corporation, 1997). The feasibility study will not be complete by the time this body of work is complete, but it has revealed many things so far. It is generally known that there is a great potential for the plant in whole to produce a variety of end products, but the end product most relative to this thesis, and offer most report on, is about the fibers for textile production.

Figure 4.1 Jennifer Bright checking on the hemp plants in Waimanalo.

Methods and Procedure

Once the first samples of the hemp became available, which came in the form of the dried out stalks, the next stage was to remove the fiber from the stalk. It is necessary to remove the fiber from the plant, and different methods for doing this have been investigated and cultivated for hundreds of years by various civilizations. The stalks had already been sitting in the field, which is known as field retting, for about two weeks before they were secondarily processed (Small & Marcus, 2015). The outer bark of the plant needed to be removed and three different methods for removing this layer, suggested by Page Chang, a prominent kapa artist in the Hawaiian community, were tried. The first method was to simply scrape the bark off while it was still on the stalk with a small oyster shell acquired from the beach, and then peel the fibers from the hurd, see figure 4.2. The second method was to remove the fibrous layer from the hurd with the bark still attached and then scrape it off with the shell while on a flat surface. The final method was to remove the fibrous layer with the bark still attached and place the whole thing into a sealed zip-lock bag with a little bit of water and let the fiber ferment and the bark decompose. After as little as one day, the bark was mostly rotten enough to rub or rinse off, leaving only the remaining fibers.

Figure 4.2 depicts hemp fiber bark being removed from the hurd as in method one.

After the bark was removed with the first two methods, the individual fibers, which were light in color, were still very much inaccessible because they were still trapped in the fiber layer and had to be processed once more in a manner similar to the third wet retting fermentation method that was used for the bark removal. The thick strips of fiber were placed into the zip-lock bag and left to sit. This was also a variable in the process because the time to ferment the fibers to release them was previously undetermined so the stages over six days were recorded.

The fermentation process started by placing all of the fibers into a Ziploc bag with enough water to cover the fibers, expelling all the air form the bag, and sealing it. The bag was left un-refrigerated and exposed to the natural temperatures of Hawai'i in late September. Each day for six days, a portion of the fibers was removed from the bag in order to be able to note the differences from day to day. Additionally, a portion of the fibers were left in the Ziploc bag to ferment for another three weeks in the October heat of Honolulu, Hawai'i in 2015, before the fibers were investigated for signs of rotting and decomposition. Apart from further separation of the major fiber bundles into individual fibers, there did not appear to be any signs of fiber rot, and actually the fibers were still strong and light in color, see figure 4.4.

Results

At the end of six days, the majority of the fibers had been predominantly released from their confinement in the bundle and looked similar to cotton See figure 4.3.

Figure 4.3 Illustrates the hemp fibers appearance after each additional day of fermentation until six days have been reached.

Further physical manipulation to the wet fermented hemp bundles at day three, day six, and again at day 28 revealed that the fibers themselves had not fermented and they began to separate with the slightest effort into long, thin, but amazingly strong fibers that retained their connection to each other, or not, for the most part, as desired and looked like a fine delicate fiber lace, see figure 4.4.

Figure 4.4 shows the hemp fiber structures as they are gently pulled in a perpendicular direction to the grain from specimen day six

Discussion

The quickness at which the fibers were released from the lignin bundles with minimal water and no chemicals during the fermenting or wet retting, indicated that pre-retting in the field could be an environmentally friendly process for early preparation of the fibers for wet retting, assert Hobson, Hepworth, and Bruce, (2001) as well as Nebel (1995), because when the plants begin to break down in the field from the sun, rain, and microbial consumption, they deposit some of their nutrients, in a beneficial process, back into the soil. If this field retting can help with shortening the wet retting time as well as with soil rejuvenation, it may be environmentally worthwhile to implement this as a regular process for fiber hemp that is grown in Hawai'i but not specifically processed for other industrial uses for its lignin.

This further highlights the strengths that hemp fibers present in environments that are dominated by the sun and moist air. It has demonstrated that it is very strong, light, and has a natural resistance to fiber rot; making it an ideal fiber choice for garments intended for use in hot and humid environments. As both field retting and wet retting processes have been revealed as possible and potentially ideal in Hawai'i, these methods can be used to help provide a higher quality raw fiber product from the beginning, or to help with fiber preparation in combination with the new technological advances in fiber extraction and manipulation, such as with the steam explosion technique. Marrying these methods can produce fibers that are fine and soft enough to produce a greater variety of high quality hemp textile possibilities, (Nebel, 1995).

Chapter Six: Objective 2 ASTM Textile Labs and Test Results Strengths and Weaknesses of Paper Mulberry and Hemp fibers when used in kapa textile

In this next chapter, five ASTM standardized textile labs were performed on four kapa textile specimens. The purpose of the following labs is to show the strengths and weaknesses of kapa textile and to determine if and in what capacity kapa might offer itself as a potential contributor towards textile sustainability for Hawai'i. The following tests were chosen specifically to expose the possibilities of kapa for use as a regular textile based on these test standards: ASTM D 1230 Flammability of Apparel Textiles, ASTM D 1388 Standard Test Method for Stiffness of Fabric, ASTM 1424 Tearing Strengths of Fabrics by Falling Pendulum type Elmendorf Apparatus, ASTM D 4970-02 Standard Test Method for Pilling Resistance and Other Surface Changes of Textile Fabrics: Martindale Tester, and ASTM 4966 Abrasion Resistance of Textile Fabric with the Martindale Abrasion Method. AATCC 22 Water Repellency Spray Test and AATCC 42 Water Resistance Impact Penetration test, as well as any wet textile portion of the labs were unable to be performed due to the unstable textile structure of kapa when wet, see figure 5.1. Fiber content, size, thickness, and textile structure are all variables to affect the test findings. The same operator and lab were used for all specimens in these labs**.**

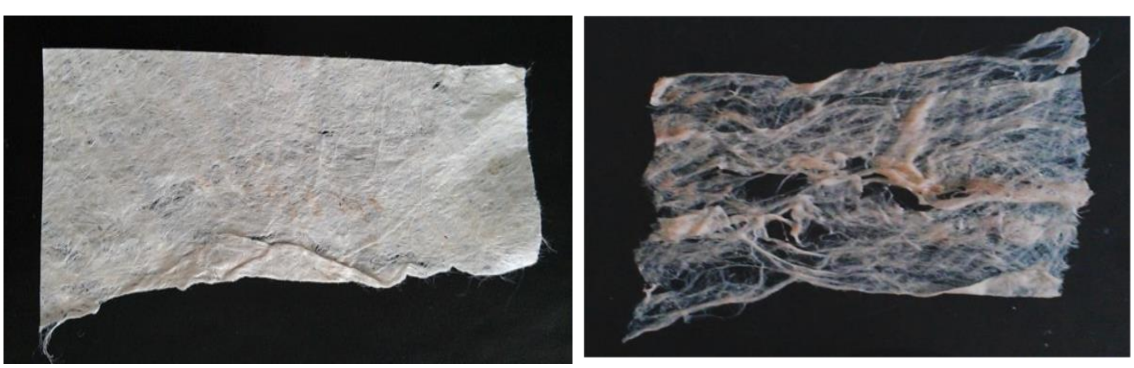


Figure 5.1 shows the unstable nature of kapa textile when wet.

Kapa is a pounded bast-fiber cloth that is made when the bark layer, containing the bast fibers, is stripped from the plant and then fermented. After the fibers have been fermented to the preferred amount, which may be different for each kapa maker, they are laid out onto a flat platform in layers and pounded with rectangular wooden tools engraved with different markings on each side of the tool which create the patterns or watermarks within the spread of the fibers when the fibers are beaten. All of the textile specimens for the following labs were made from fibers that were grown in Hawai'i and created in this kapa style by a Hawaiian kapa artist, Page Chang. Three of the specimens are made of the traditional fiber plant, *Broussonetia papyrifera*, known as paper mulberry, are lightweight, medium weight, and heavyweight. The final specimen, also heavyweight, is made from cannabis sativa, or hemp. These specimens used throughout the multi-lab report will be known as: **1** –lightweight paper mulberry, **2** -medium weight paper mulberry, **3** –heavyweight paper mulberry, and **4** –hemp. Some deviations to the labs were necessary; 1) only four specimens were presented in this lab, one specimen per each type was used due to lack of availability of sample, 2) specimens were cut according to the fit of the specimen test pattern on the allotted textile for the test, and not in relation to any grain that may be present as a result of the intrinsic nature of the pounded bark-fiber cloth.

The ASTM tests were all conducted on the third floor of Miller Hall in the textiles lab of the Fashion Design and Merchandising program in the College of Tropical Agriculture and Human Resources at the University of Hawai'i at Mānoa on the same day, with the exception of the abrasion and pilling tests; which were re-conducted at a later time because of human error the first time the tests were run. The following figures of graphs and charts illustrate the results of the labs conducted on the kapa style textile specimens. Full copies of the labs can be found in the appendix.

The objective of ASTM D 1230 Flammability of Apparel Textiles lab is used to measure and assess the specimens under actual fire conditions by subjecting the specimens to a standardized test and then offering a class rating for the textiles based on the results of the test. There are three class ratings for textile flammability; class I are considered acceptible for apparrel, class II are considered to have flammable characteristicts, and class III are not suitable fo apparrel. All of the following specimen rated as class I textiles and are considered acceptible by those standards. Figure 5.2 shows that the heavyweight paper mulberry kapa took the longest to burn and that hemp kapa took the longest to ignite.

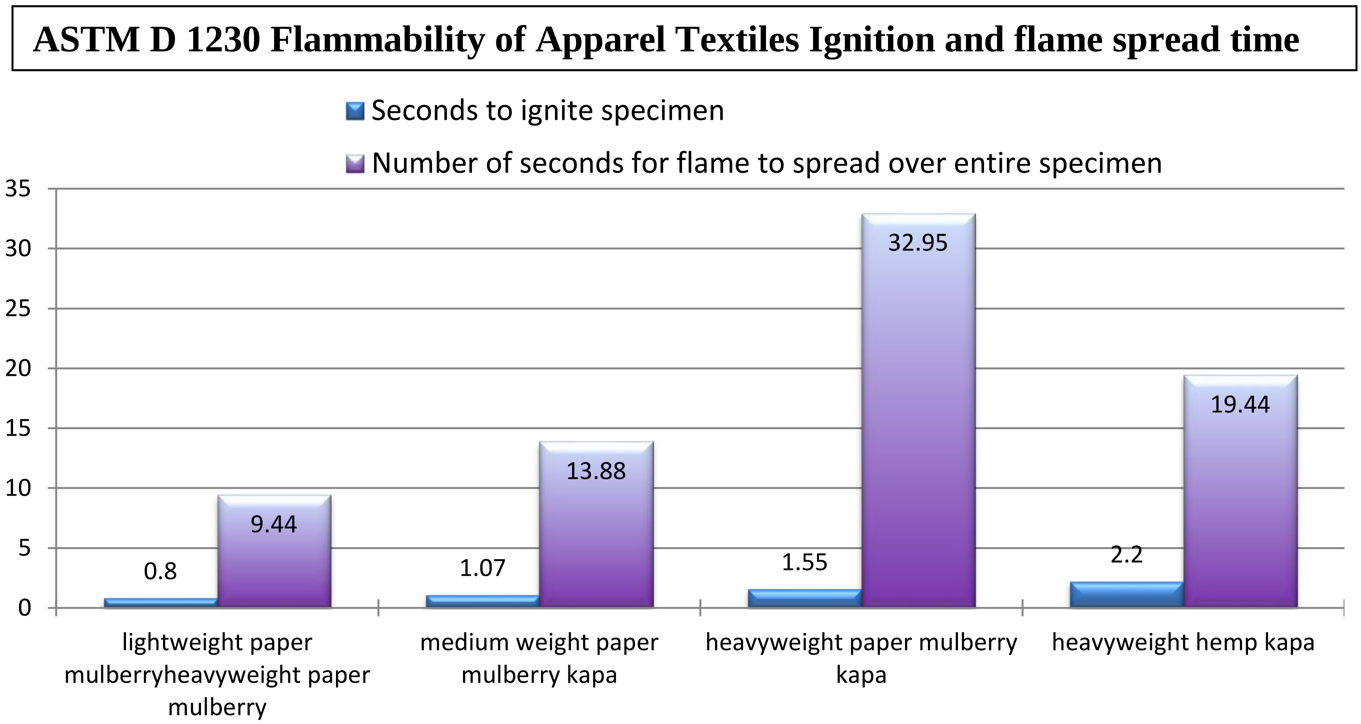


Figure 5.2 shows that the heavyweight paper mulberry kapa took the longest to burn and that hemp kapa took the longest to ignite.

This flammability test does not imply that a class one determination rating for the flammability of these kapa specimens is making any other statement about the nature of the kapa textile in regards to strength or other properties it may or may not possesses relating to the standards of regular garment use. This data may be more suggestive to the flammability properties of the particular fibers more than the construction of the textile; however, further tests with greater variation of kapa, as well as the woven textile versions of these fibers, would need to be conducted to explore this.

The objective for ASTM D 1388 Standard Test Method for Stiffness of Fabric is to guide the designer in the design process by offering data that is relative to the end use suitability of particular textiles based on their stiffness. This test revealed that the kapa textile in general was very rigid, especially as compared to other woven textile specimens. The kapa specimen were new and had not been rubbed to produce a more lenient hand, and so softer or older kapa may provide different results, but the nature of the rigidity of the kapa seemed to be determined by the structure of the textile due to the fact that it has no woven or knit intersections to provide for pliability. Hemp and paper mulberry both provide bast fibers, so their rigidity may also be an intrinsic factor of the fiber coming from the bark of the plant. Woven versions of hemp and paper mulberry textiles would need to be tested against other woven textiles to assess the fiber rigidity versus the textile structure rigidity. This data suggests that both hemp and paper mulberry kapa would be useful in situations where a stiffer hand is desired which can create a more full bodied or structural appearance in garments. This effect can be seen in the traditional mele hula dancing where kapa is present in the hula garb. Figure 5.3 shows that the heavier the weight of the specimen, the more weight resistant it was to bending, requiring more weight per cm^2 to cause bending.

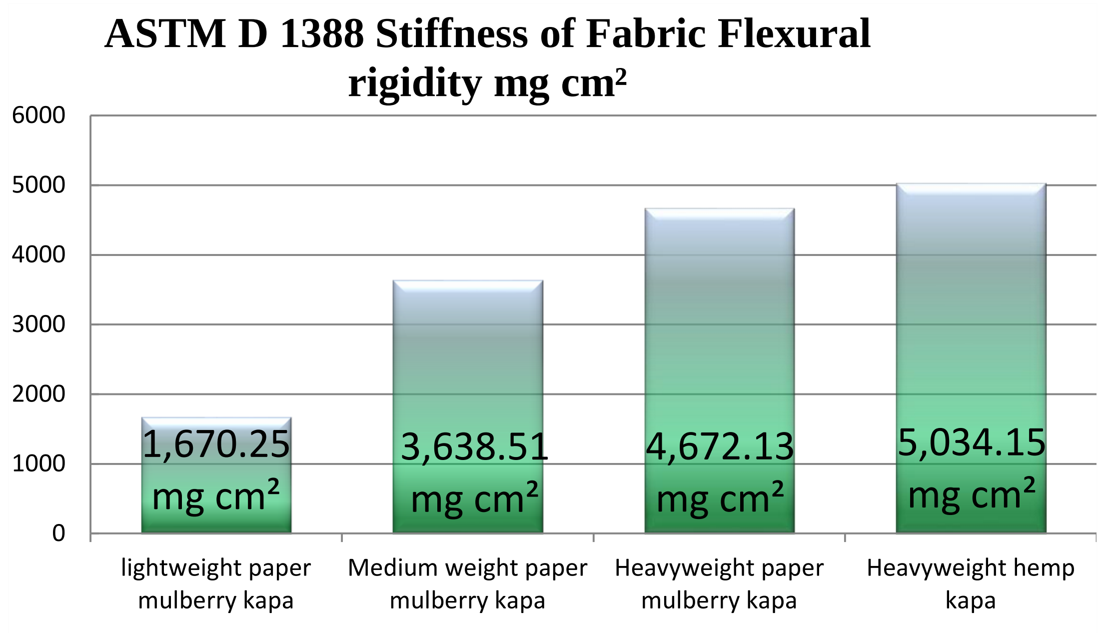


Figure 5.3 illustrates how much weight is needed to bend the specimen, or shows the specimen rigidity.

ASTM 1424 Tearing Strengths of Fabrics by Falling Pendulum type Elmendorf Apparatus has a simple objective in that it determines the tearing strength by measuring the resistance of a fabric in grams or pounds of force required to cause a single tear in the textile. The kapa specimens from this lab have been compared to each other as well as compared to other woven textiles put through the same testing at an earlier date by the same operator and in the same lab using the same equipment, see figure 5.4. The following chart tells an interesting story, but may be hiding a convoluted truth. The heavyweight hemp kapa specimen tore along the grain and path of least resistance and offers the lowest numbers, so This particular test has revealed that the kapa constructed using the current methods of making kapa, using these two fiber possibilities, has a limited strength ability as a textile designated for regular use, because of the structure of the textile and not because of the nature of the fiber itself. This test is pointing out the strength of the hemp fiber in this case and revealing the weakness of the kapa textile structure. The woven specimens from the previous lab show that great strength in these textiles seems to come from the woven structure, as well as the fiber type. This lab also reveals a question of how to increase the strength of the non-woven textile; which might be answered somewhere in the process of making the kapa textile.

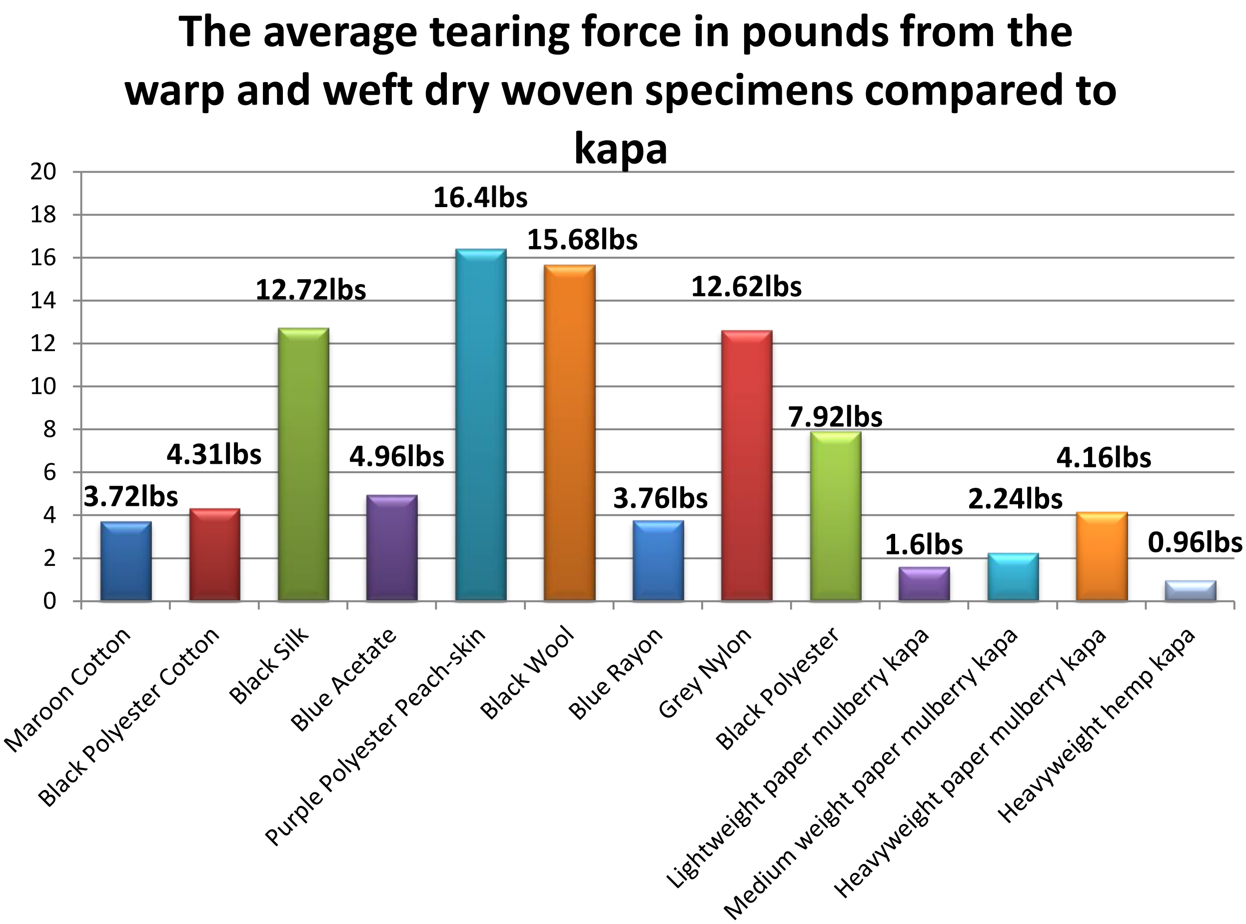


Figure 5.4 shows the tearing force of kapa as compared to various other fiber types and textile weaves.

As the puzzle picture of the kapa textile is filling in and proving to have strengths and weaknesses, the next piece of the puzzle can be filled with the ASTM D 4970-02 Standard Test Method for Pilling Resistance and Other Surface Changes of Textile Fabrics: using the Martindale Tester. The objective was to determine the pilling resistance of kapa in particular, because this test that reveals the weaknesses of the textile as it pertains to a small amount of rubbing against an abrading fabric. The test used a standardized abrading fabric, which is used as a simulation for other textile types such as denim, peach-skin, or jersey knit. The lightweight kapa specimen exhibited the most pilling and the heavyweight kapas demonstrated that they were resistant to pilling, see figure 5.5. This indicates that a thicker kapa textile may be more suitable for end uses that involve a bit more rigorous use than the more delicate lightweight kapa.

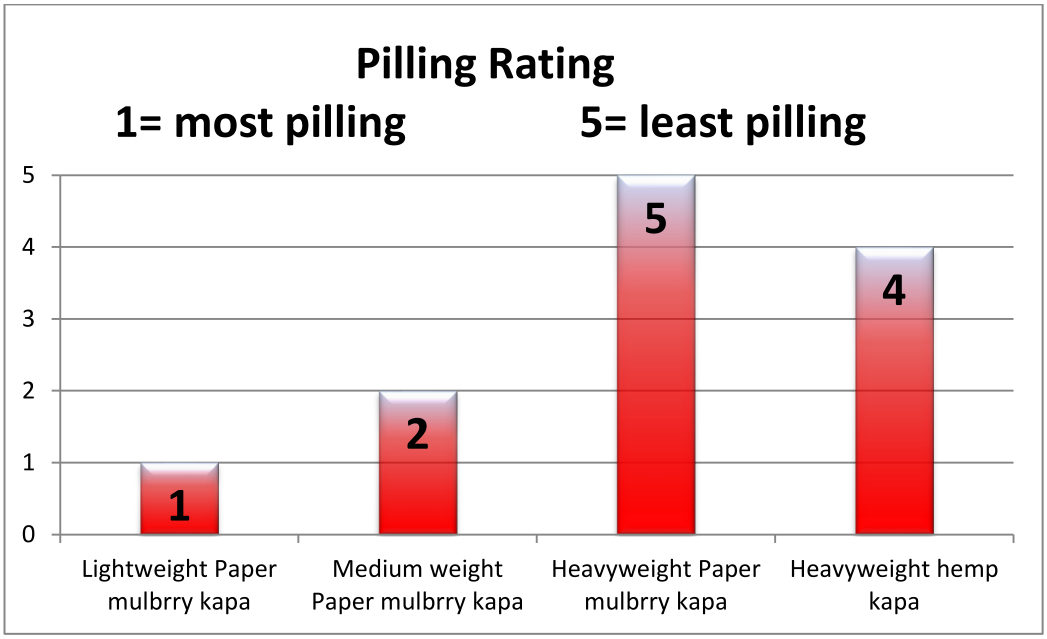


Figure 5.5 shows that lightweight paper mulberry kapa pills the most and heavyweight paper mulberry kapa pills the least.

The fifth and final piece of the picture is revealed with the results from the ASTM 4966 Abrasion Resistance of Textile Fabric with the Martindale Abrasion Method. This test was conducted to determine the amount of abrasion that is necessary to render kapa useless or destroyed. The lab is supposed to run for 25,000 rotations, but none of these kapa specimens came anywhere close to finishing that number of rotations before they were destroyed. The percentage of the specimen lost to the abrasion was significant, and the whole test was concluded within 3,600 rotations. Figure 5.6 shows the heavyweight paper mulberry kapa was the overall best performer because it had the second least amount of fiber loss of the four specimens, but it lasted the longest having more than 1,000 rotations more than the next longest lasting specimen, the hemp kapa. The hemp kapa would have lasted longer, but the length and strength of the hemp fiber actually became a detriment to the specimen. This indicates that if the hemp fibers had been shorter in length, the specimen might have lasted longer, but it also suggests that the thickness of the kapa and the size of the fibers are determining factors in the specimen's ability to withstand abrasion.

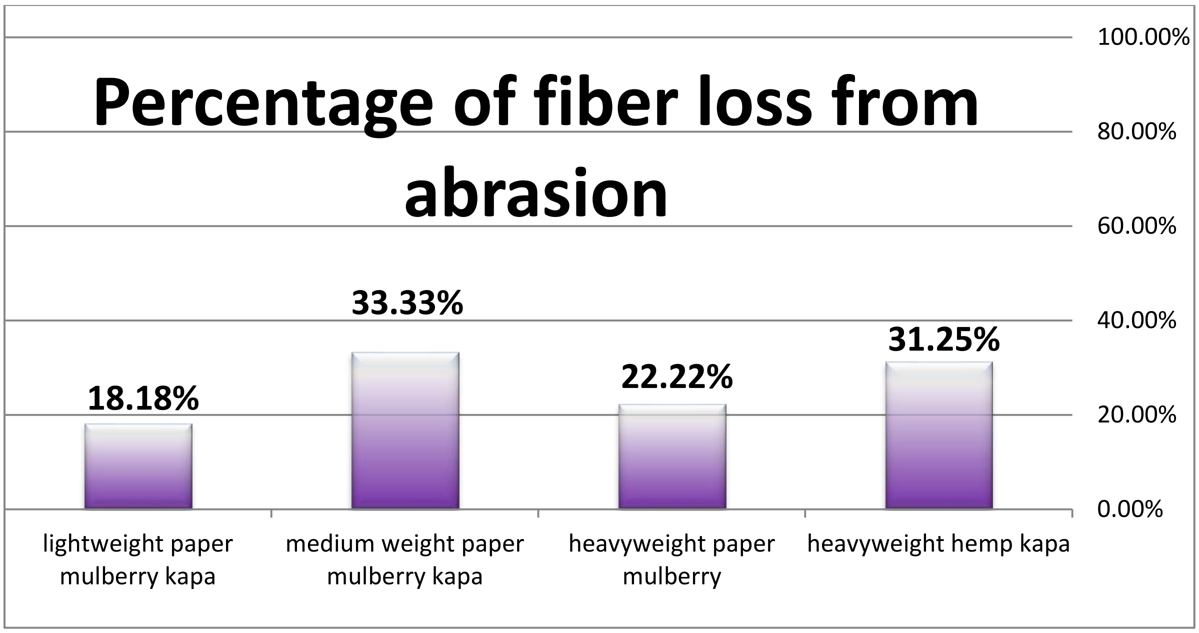


Figure 2.6 shows that the medium weight kapa lost the greatest percentage of fibers at 33.33%.

ASTM lab Conclusions for kapa textiles:

Each fabric is unique in its properties, but with the known behaviors of fibers of natural origin and synthetic, estimations of various testable occurrences and amounts can be generally made. These tests, however, need to be conducted several more times with more kapa pounded from both hemp and paper mulberry because the information from these tests, among others, can really help the manufacturer and consumers understand this special textile, kapa. These test results show that each fiber type, weave structure, and textile structure of non-woven specimens, can create a special circumstance with which it might be difficult to cross analyze, however, kapa makers, or designers who wish to make or incorporate kapa into their designs, would be interested in knowing what these test results reveal, and will be able to provide and apply this knowledge to their products. Information from these tests will help in the design, manufacture, purchase, and consumer care of items if these issues are properly addressed and solutions are made available to the consumers through correct and informative labeling practices.

Standard test methods are beneficial for the textile industry; as tests on the various characteristics, strengths, and weaknesses of fabrics are critical to the development and production of well-informed and well-designed quality made products that can perform to end use specifications within reasonable standards. The strengths and weaknesses of these particular kapa style textiles is of ever more importance in Hawai'i as non-woven textiles are seeing a broader range of application and frequency of use that commands the knowledge/information that can be gleaned from standardized tests, (Collier, Bide, & Tortora, 2009; Humphries, 2004). These tests contribute to establishing standards for the textile community no matter who the consumer is of the results.

Kapa has revealed through these tests that in general, it is a textile that could not be used for regular garment use according to standardized procedures. One main reason is that it is extremely susceptible to water and cannot be washed as a normal garment would be. Kapa made from both hemp and paper mulberry, however, have been classified as class one textiles for the flammability ratings which may suggest that the fibers themselves may possess the rating over the textile. These tests also showed that kapa in general is a very stiff textile and so may be fashioned towards uses needing a firmer hand. Kapa is also a textile that does not require much force to tear, so it may need additional surface treatments to preserve the textile, or the product end use may need to be limited. These tests also disclosed that the pilling factor is relatively high with the lighter weight specimens than with the heavier weight kapa, and that none of the specimens could stand up to full number of rotations to complete the abrasion test.

All of that being said, there is an emerging market for products made from these locally created and culturally significant textiles, however, this collection of data suggests that kapa textile maybe better suited to a luxury textile product level, and for products keeping more with a fine art presentation, or for limited use in particular high-end garments and products, than for use in regular garment type presentations.

Chapter Seven: Hawai'i's Tourism Industry meets the Garment Industry

The global standards for what luxury means also seem to be under societal review with the current movement towards being eco-friendly which is also generally referred to as the, 'green movement' (Ghadimi et al., 2013; Karthik et al., 2015). Even the fashion schools such as the Fashion Institute of Technology in New York, are teaching the students that there is a shift in the consumer values that define the meaning of luxury, with a 2015 student capstone assignment called, The Future of Luxury. One of these capstone projects, entitled, The Future of Luxury: New Luxury Consumer Values, by Burdine, Cho, Levis, and Marks et al. (2015), describe an evolution of thought amongst consumers that involves a switch to an interest in legacy as a means of environmental mindfulness. Burdine et al. (2015), go on to explain that memory and value are interconnected and provide an avenue to achieve this resurgent desire to leave a legacy. Now, the more in tune with the culture they represent, and the more environmentally friendly that luxury entities can present themselves, the more companies are regarded with prestige, and products with desirability, the more they will be able to offer this 'legacy' that is so desirable (Ghadimi et al., 2013; Karthik et al., 2015; Burdine et al, 2015).

Younger generations of consumers are collectively showing signs of wanting individualism of fashion versus the lingering concept of fast fashion (one in a million). Consumers are now showing signs of wanting the logos and brand monograms on the clothing to have actual meaning and social status, not just be a symbol that is supposed to imply status through hype in the price, but rather have actual symbolic status through responsible means of business operation and product production. In addition to this, people want truth of apparel, meaning; if one visits Hawai'i from China, one probably does not want to purchase a shirt in Hawai'i that came from China for several times more than the amount they would pay for the same shirt in China. If a consumer is interested in a location specific souvenir, one might feel cheated if the item has been imported and falsely advertised as authentic to the location. These issues comes into the spotlight lately because one of the islands well knows tourist destinations for “Hawaiian” souvenirs and ‘Aloha’ shirts, Hilo Hattie, filed for bankruptcy in 2008, and eventually closed most of its doors to business in an attempt to evolve into a business focused on broadening the tourists’ cultural experience, through performance and sharing local culture, versus the predominant sales of items, a large bulk of which were not made in Hawai’i (Honolulu Star-Advertiser, 2015; Pacific Business News, 2009). Since travel is often included in the memorable experiences that are of more interest to the consumer, it stands to reason that the souvenirs of those memorable experiences, that have the ability to offer an honest legacy of that time spent, will be the ones that the consumer brings home (Burdine et al, 2015).

Hilo Hattie had been promoted, and known internationally, as a tourist ‘go to’ location for Hawaiian souvenirs, and aloha shirts, since opening in 1963 (Arthur, 2000). Unfortunately, Hilo Hattie declared bankruptcy, but in my opinion, if they had offered the tourists products that were indeed made in Hawai'i and also exclusive to Hawai'i, then perhaps Hilo Hattie would still be a thriving business today. Fortunately, Hilo Hattie is making a company move towards offering the Hawaiian cultural experience as a memento, which is an important step towards recognizing what the tourist of today is interested in, and may be instrumental in the ultimate survival of this long time Hawaiian company.

In addition to wanting honest and individual fashion, the political climate, economic climate, social environment, as well as technological advances, and other factors at the time can all completely alter the forecast of any consumer purchasing intentions. To ruminate, an American serviceperson in Hawai'i looking to get a good aloha shirt, might not want to buy a product imported from a foreign county if the political tensions between that country and the United States are high. This is especially important for Hawai'i because a large number of businesses in Hawai'i depend on the tourism industry, the military industrial complex, and the transient students for the continued economic support; either through direct or indirect flow from these renewable resources. Another realistic and current example of this can be seen in the increased social awareness and more recent mass acceptance of *Cannabis sativa* in the American culture as the industrial, medicinal, and recreational aspects of different cultivars of this species are explored. This new social acceptance allows for the possibility laws and regulations to change that could positively affect many industries across the board, and in the case of Hawai'i, potentially allow for an entire textile industry to successfully exist.

The Hawaiian image is part of this projected legacy, and large numbers of people travel huge distances, thousands of miles, to have the Hawaiian experience. This year alone the Hawai'i Tourism Authority (2015) reports that in 2014, Hawai'i experienced 8.3 million visitors who collectively spent 14.7 billion dollars, and as of August 2015, Hawai'i has attracted more than 5,785 million worldwide visitors, and a general increase in numbers from last year, with the exception of fewer visitors from Japan, see figure 6.1.

Visitor Arrivals* by Market (August, 2015)

Market	MONTH			YEAR-TO-DATE		
	Current	Yr. Ago	% CHG.	Current	Yr. Ago	% CHG.
US West Market	313,181	304,608	2.8%	2,390,097	2,220,018	7.7%
US East Market	146,052	142,622	2.4%	1,262,127	1,233,954	2.3%
Japan Market	157,543	156,690	0.5%	980,164	990,670	-1.1%
Canadian Market	28,214	25,924	8.8%	360,634	359,727	0.3%
All Other Markets	110,871	104,841	5.8%	792,723	737,563	7.5%

*Includes visitor arrivals by air only
Source: Hawaii Tourism Authority

Figure 6.1 illustrates the increase of visitors to Hawai'i in 2015 from 2014.

Figure 6.1 does not fully illustrate the influx of visitors coming from China, but it is important to note that The Hawai'i Tourism Authority (2015) has separately listed a huge percentage jump in visitors from China in 2014, up over twenty eight percent to more than 160,000 visitors, and also that the Chinese visitor was likely to spend at least twice the daily spending of Japanese tourists, increasing to $399 per person in 2014.

One can easily see when walking down the street in any tourist area, that the tourists are spending money, walking in and out of shops and often in their new and frequently matching "Aloha attire" for the whole family. It takes only one step to look at actual visitor numbers seen in figure 6.1 to realistically speculate that if half of the people that came to Hawai'i purchased only one aloha garment such as a shirt or dress or shorts, the end result is that 2.9 million garments would be sold every year! If each of these garments cost $25, the sales produced from this small fraction of this market alone would be just over $72.5 million dollars. This indicates a significant amount of worldwide interest in Hawaiian culture specifically as it has been expressed in clothing and presents a fine case for why garment manufacturing in Hawai'i should continue and why the industry could grow. It may be that many people purchase more than one item of aloha related attire, and many individuals spend considerable amounts more than $25 total. If a majority of this money could stay in the state, Hawai'i would benefit greatly.

Page six of the Industrial Hemp Study done in Hawai'i by the ADC claims that there have been lands and workers in "dire need of new employment" since the sugar cropping came to an end (Agribusiness Development Corporation, 1997). If these fields had been filled with industrial hemp or cotton, the workers might have had a chance at a profitable livelihood growing these plants for various industries of Hawai'i including a textile industry, as they are incredibly versatile in their product offerings, especially hemp (Hemp Technologies, 2008;

USDA, 2000; Yonavjak, 2013). If Hawai'i had its own ‘homegrown’ textile industry and that produced world class textiles that locals could turn into exclusive Hawaiian manufactured goods, businesses like Hilo Hattie and others would have been able to use and promote these Hawaiian textile goods as exclusive and truly Hawaiian to the benefit of all involved in the production of said goods. Locational or political conflict might not be present in the mind of the consumer at the moment of purchase, only satisfaction at receiving a genuine Hawaiian product.

It may turn out that industrial hemp could provide the predominant relief to the familiar need and recent demand for sustainability that has presented itself in Hawai’i (Hemp Technologies, 2008; Yonavjak, 2013). Hemp can be grown in such a way as to offer soil remediation, soil rejuvenation, food crop rotation, reforestation, and when sold at a fair price for the industrial and luxury commodities markets; hemp farming could produce more socially responsible wages for the farmers growing this crop (Hemp Technologies, 2008; USDA, 2000; Yonavjak, 2013). Hawaiian hemp and other locally produced textile products can then be sold to the Hawaiian market at the higher-end exclusive levels that would be required to support this industry. This is possible because a market for Hawaiian influenced and exclusively Hawaiian made items will exist into perpetuity, unless Hawai'i falls out of favor or interest with the world. Even if this does occur, history has shown that this, too, has been cyclic, and one need only wait for the next Hawaiian renaissance.

Honolulu is experiencing a surge of investment that is directly related to the fashion scene, as Ala Moana Shopping Center, commonly known as the world’s largest outdoor mall, is getting bigger with a whole new wing that will have a grand opening November 12, 2015, and will be hosting several more large department stores. On foot and online research into nationally recognized chain stores operating in Hawai'i for fashion purposes, such as Neiman Marcus, see figure 6.2, Bloomingdales, see figures 6.3, Macy's, see figure 6.4, and Nordstrom, see figure 6.5, has indicated through garment prices and sold out sinage that there is in fact a market for modern $100- $1,600 shirts being sold in Hawai'i. None of these garments listed for sale are made from exclusive Hawaiian textiles, and extremely few of which are actually manufactured in Hawai'i, see figure 6.6, and yet the Hawaiian inspired shirt market is still very active! The vintage Hawaiian shirt market also supports the prestige and legitimacy concepts that the 'aloha' shirts that were actually manufactured in Hawai'i, such as Tori Richards and Reyn Spooner brands are far more expensive than the ones that were not, see figure 6.7, (Arthur 2000). This niche market combined with new memory oriented luxury item marketing strategies could be applied to the exclusive products being made in Hawai'i from Hawaiian textiles. Using locally produced raw materials and textiles such as industrial hemp, kenaf, lauhala, cotton, pineapple leaf fiber, and kapa, Hawai'i can support a textile industry which could then support a sustainable fashion industry.

Organic raw materials can be grown, and harvested in Hawai'i for the purpose of supplying and supporting a small, sustainable, and exclusive textile industry as a partial solution to this sustainable textile need. It is most probable that Hawai'i can provide the raw materials for the textile industry to make the products, yet there is still much research and technology development that needs to happen. The question is then; could the products be sold in such a way as to make it sustainable or economically viable enough to exist into perpetuity? In order to fully investigate the possibilities of textile sustainability, a variety of fiber sources (new and old sources) are being actively researched and explored across the globe to provide alternative and viable sources of fiber for the textiles of our lives (Karthik et al., 2015). Hemp would more than likely be the best fiber provider for Hawai'i for regular use garments, and could be marketed as a luxury Hawaiian product, and the garments made from it could be presented with the same prestige that only other uniquely Hawaiian products can boast. This unique distinct and rare Hawaiian character, smell, flavor, texture, concept, or often just the isolation of the islands' location is scintillating enough to the human senses to warrant products containing 'it' as something special, worthy of notice and care.

Figure 6.2

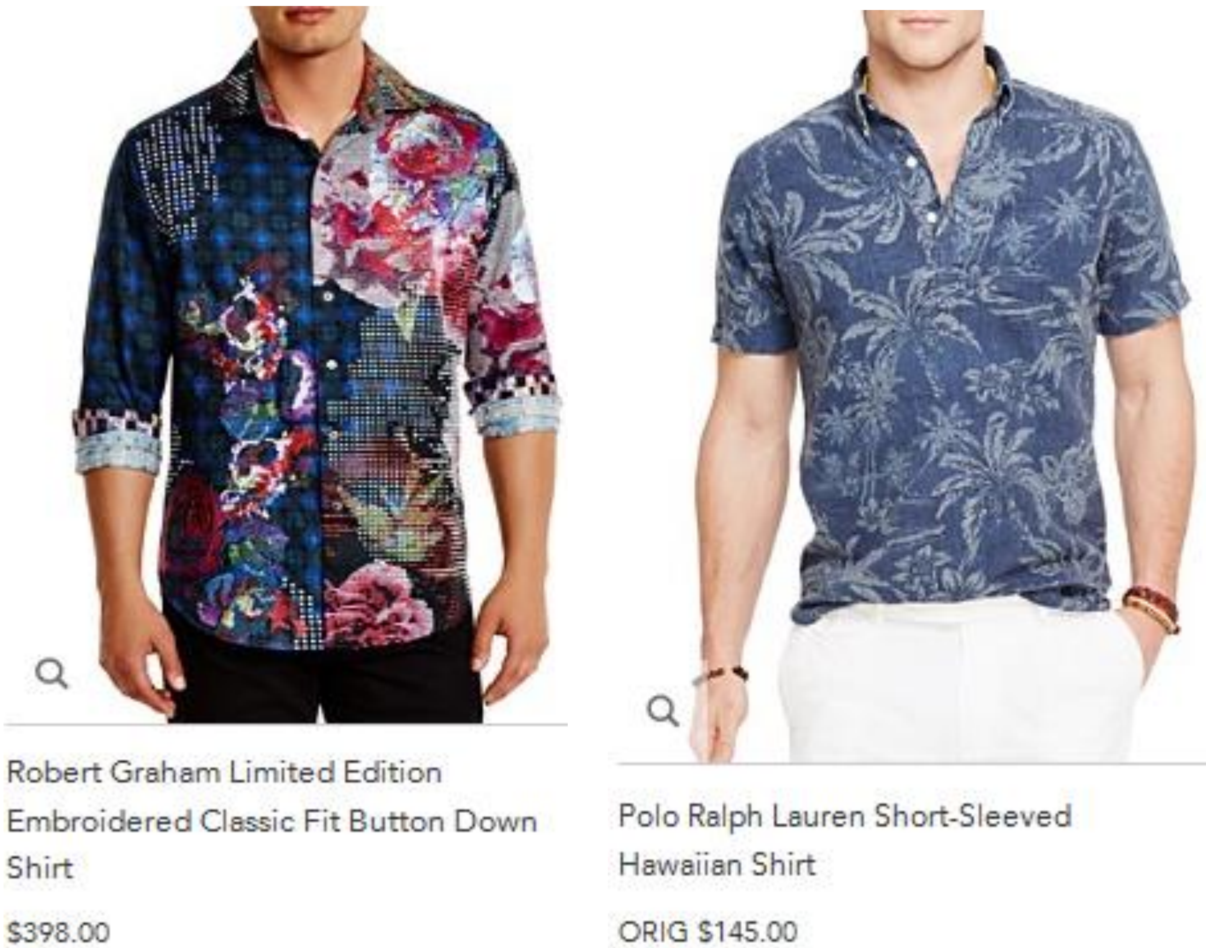


Figure 6.2 shows two aloha style shirts from Neiman Marcus ranging from $145 to $398. Retrieved from http://www.neimanmarcus.com/Apparel/Polos-Tees/

Figure 6.3

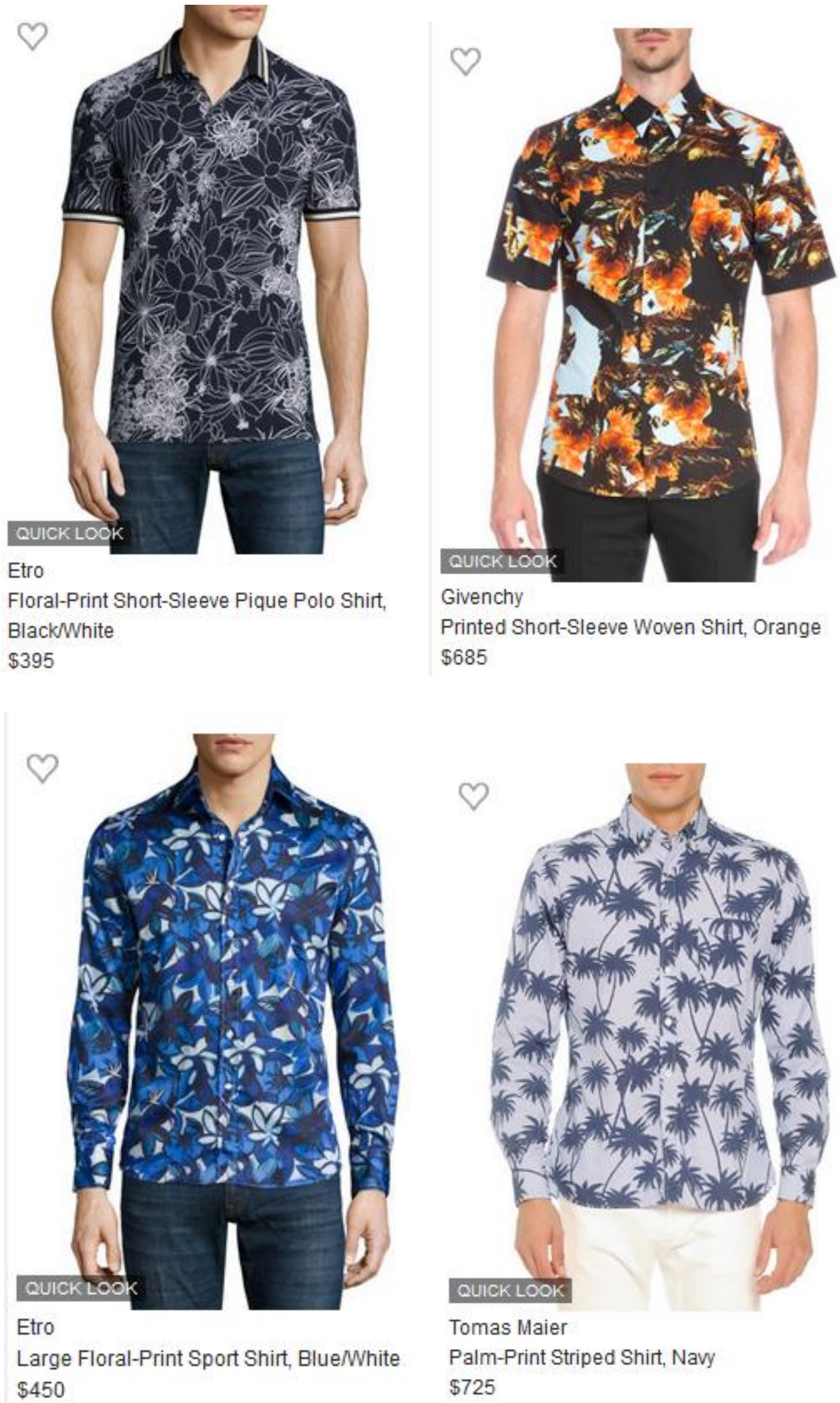


Figure 6.3 shows various aloha style shirts from Bloomingdales that range from $395 to $725. Retrieved from http://www1.bloomingdales.com/shop/search?keyword=mens+hawaiian+shirts

Figure 6.4

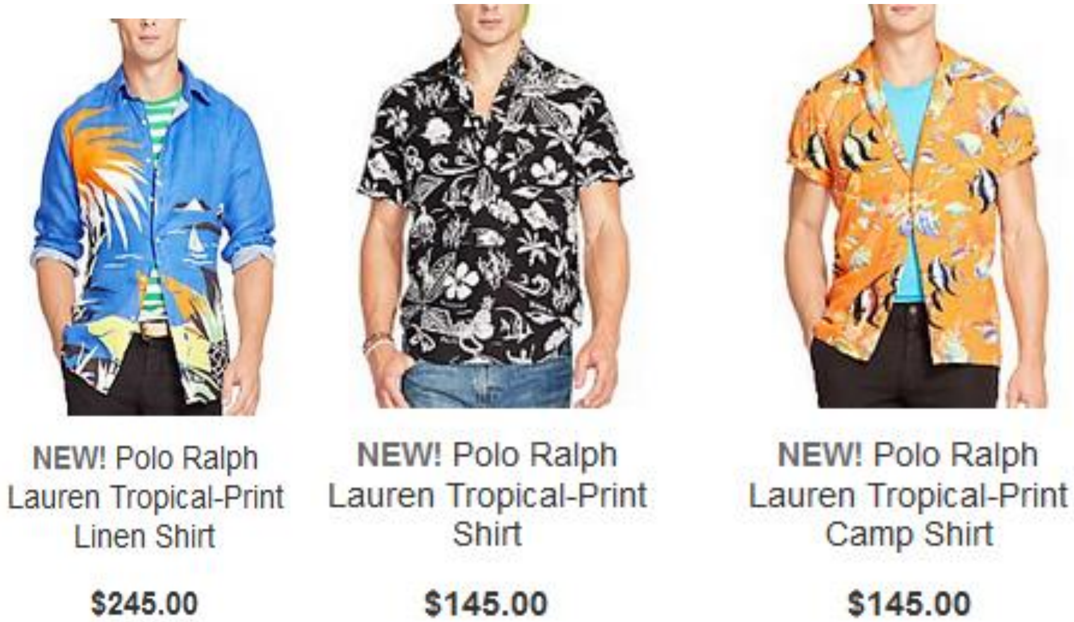


Figure 6.4 shows various aloha style shirts from Macys that range from $145 to $245. Retrieved from http://www1.macys.com/shop/search?keyword=mens+hawaiian+shirts

Figure 6.5

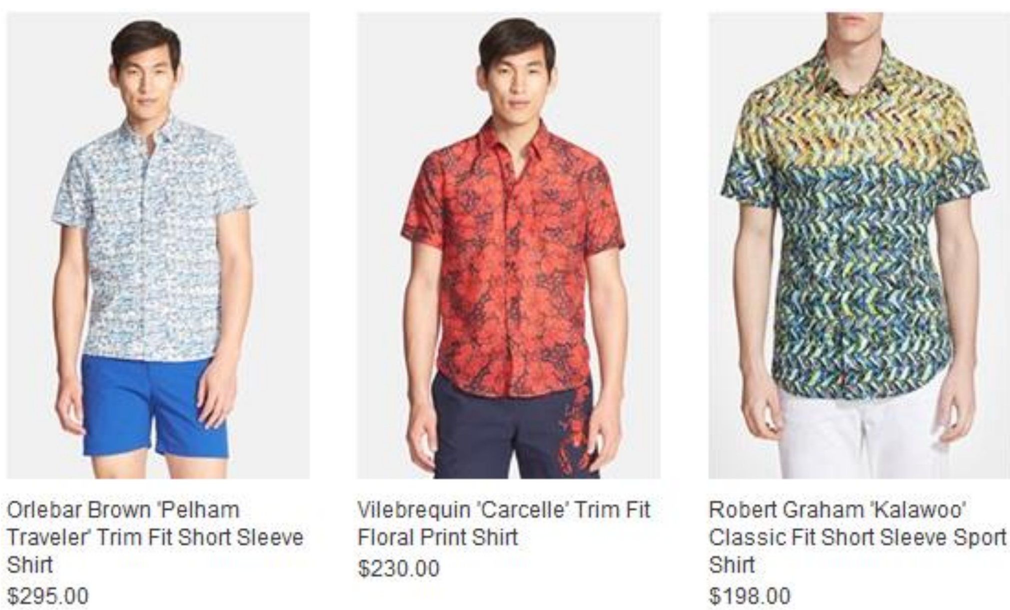


Figure 6.5 shows various aloha style shirts from Nordstrom that range from $198 to $295. Retrieved from http://shop.nordstrom.com/sr/hawaiian-shirt

Figure 6.6

Figure 6.6 shows shirts that were actually manufactured in Hawai'i from imported fabric. Retrieved from https://www.alohaoutlet.com/Shops/108/en/Search.aspx?CatId=1153

Figure 6.7

Figure 6.7 shows several vintage aloha shirts of various brands, all made in Hawai'i and ranging from $799 to $999. Retrieved from http://vintage-aloha-shirt.com/shop/index.php?cPath=43_67&osCsid=t2cvaafjr906peqtu49aumoai1

Chapter Eight: Objective 3 – Hawai'i's raw products, local luxury brands, and sustainable business practices

Luxury products are more than likely crafted with careful consideration, precision, and perhaps lovingly, from the finest materials into products that are high in design, functionality, responsibility to the land and people, and might provide a sense of satisfaction to own above that of products that attend to the basic needs of life. Hawai'i provides the raw materials for several luxury items and products that help to support the local economy. This includes a few species of plants in particular are already well known in some luxury markets. *Acacia koa*, *Aleurites moluccanus* (kukui nut), *Macadamia, Coffea sp.,* and *Theobroma cacao* (chocolate), are all plants that immediately come to mind when thinking about Hawaiian produced luxury products. Each of these raw materials, when grown in Hawai'i, offer products that are specific to Hawai'i and that have also tapped into the truly local luxury markets here. What makes each of these products luxury begins with the location of growth for the raw product, in combination with the local crafting, local processing, local packaging, and local sales. The following examples illustrate local companies promoting each of these different raw products. These examples are by no means the full spectrum of what is available.

For endangered and endemic species such as *Acacia koa,* restorative practices are being activated on private land that will offer economic incentive to grow this endangered and culturally significant hardwood (Pejchar, & Press, 2006). The 53 year old Hawaiian based company, Martin and MacArthur, who specializes in Koa wood products; from furniture to fine watches, cell phone cases, wedding rings, sunglasses and more, claim to take a leading role in the reforestation of Koa, see figure 7.1 (Martin & MacArthur, 2014). In addition to not using any wood from live or cut trees, and reforesting the land, Martin and Macarthur are assisting the community with 35 artisans in employment (Martin & MacArthur, 2014).

Figure 7.1 illustrates two luxury koa watches by Martin and Macarthur. Retrieved from https://www.martinandmacarthur.com/

Aleurites moluccanus, or kukui nut, is another locally grown species that produces a high quality product; kukui nut oil. In addition to the exterior of the nut being used as lei, the interior of the nut is used to make oil that is used for external health applications. Oils of Aloha is a Hawaiian company that since 1988 has been specializing in the production of kukui and macadamia nut oils for a variety of healthful purposes, see figure 7.2 (Papania, 1988). Kukui oil is known to assist in the healing and moisturizing of skin by maintaining the integrity of the intracellular structural of a layer in the epidermis known as the stratum corneum, and by providing a source for Omega-3s (Ako, Kong, & Brown, 2005; Papania, 1988). Many of the most highly respected cosmetics companies use kukui nut oil in their products because of these healing and moisturizing properties (Papania, 1988).

Figure 7.2 shows a collection of the products from Oils of Aloha. Retrieved from http://oilsofaloha.com/About-Us.html

Even though the Macadamia is native to Australia, it has quite a distinct history in Hawai'i since 1882, and continues to directly influence the islands and other international locations (Hamilton & Fukunaga, 1959). There are a plethora of positive reasons for growing this nut; its consistency and flavor, as well as the lucrative price the nut commands on the market, and add to that the increased value to the land from the various areas of reforestation in Hawai'i that have occurred as a result of the restorative cultivation of this crop tree; and the Macadamia stands tall, now firmly rooted in the story of Hawai'i (Hamilton & Fukunaga, 1959). As far as world renowned confectionaries are concerned, it is considered to be one of the choicest nuts, and as Oils of Aloha has also established, macadamia oil is not only healthy and delicious, but it is also used in addition to Kukui nut oil in premium cosmetics and pharmaceutical applications. (Ako, Kong, & Brown, 2005; Hamilton & Fukunaga, 1959; Papania, 1988). As some cultivars of the tree release portions of their nut harvest every month, it is a particularly viable crop in locations that support the year round and intermittent flowering cycles, such as Hawai'i. M. *integrifolia* was noted by Hamilton and Fukunaga (1959), on page five of their article, *Growing Macadamia nuts in Hawai'i*, as being one of the most promising crops up for consideration at the time.

When it comes to *Coffea sp.*, it seems as though the whole world knows about Hawaiian grown coffee, most famous being the coffee which is grown in Kona, Hawai'i, but there are other Hawaiian estates that produce this exclusive commodity as well such as Ka'u Coffee also from Big Island, and the Green world Coffee Farm on the North Shore of O'ahu, see figure 7.3. These sales of these luxury coffee products that are grown in Hawai'i offer locals increasing variety of employment opportunity, and keep more of the economic benefits in the state. Since Hawai'i is the only state in the United States to grow coffee, which makes it a perfect example of another unique and rare product that is exclusive to Hawai'i.

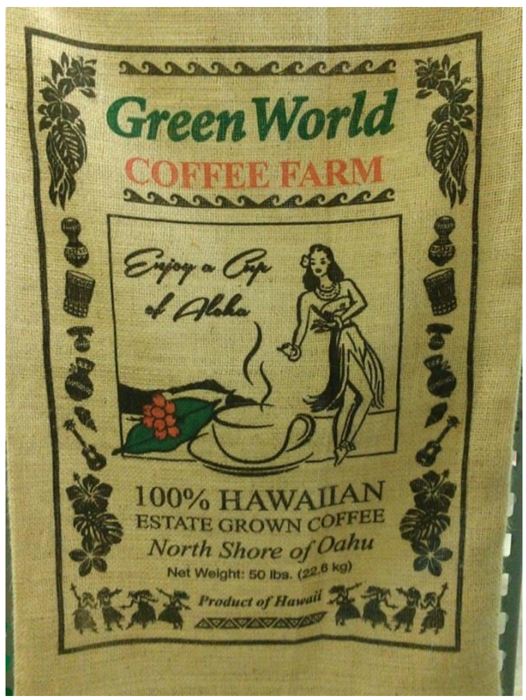


Figure 7.3 shows the coffee bean bag from Green World Farm on the North Shore of O'ahu.

Another popular item that is specific to Hawai'i luxury items, is chocolate, *Theobroma cacao*, and whether it is Forestero, Criollo, Trintario, or another variety, the chocolate that is grown in Hawai'i, being the only cacao grown in the United States, is truly unique in this world (Conway & Lanter, 2015; Original Hawaiian Chocolate Factory, 2009). Being that the flavor is so unique as a result of the location; some companies that have developed in Hawai'i to grow cacao and craft chocolate have chosen not to blend it with cacao from other locations so as not to dilute the true nature of the Hawaiian influence to the product, thereby producing award winning and rare chocolate that is sought after by the international chocolate connoisseurs see figure 7.4 (Conway & Lanter, 2015; Original Hawaiian Chocolate Factory,2009). All of the companies that grow and produce Hawaiian chocolate in Hawai'i using production techniques that are sustainable, are creating local employment opportunities and formulating a more extraordinary local luxury product reflective of the exotic nature of Hawaii (Conway & Lanter, 2015; Mānoa Chocolate Hawai'i, 2010; Original Hawaiian Chocolate Factory,2009).

Figure 7.4 shows three different chocolate products from Waialua Estate on the North Shore of O'ahu. Retrieved from www.waialuaestate.com

An example of a sustainable luxury Hawaiian product is not a single product at all, but rather a local aquaponics farm that sustainably supplies organic vegetables to the community while employing members of the community as well is ‘Ili’ili Farms. ‘Ili’ili farms has stated that they are committed to sustainability and food security for Hawai'i through the use of higher yielding organic aquaponics techniques that can put un-farmable land space to use growing crops with less fertilizer and significantly less water needs than similar crops grown in the ground, see figure 7.5. They employ locals and the provide their products in locations such as Whole Foods and Down to Earth which are known to be luxury food chains because of their products that attempt to adhere to higher quality and more responsible social standards ('Ili'ili farms , 2015).

Figure 7.5 shows the sustainable hydroponic farm tables at 'Ili'ili Farms on O'ahu. Retrieved from http://www.iliilifarms.com/#!about/c15v1

These examples all illustrate the possibility of conducting sustainable businesses in Hawai'i while using the natural resources and conditions of the location to cultivate and promote their unique products. The distinct conditions present themselves the same if industrial hemp were to be grown in Hawai'i. It, too, could be manufactured into a variety of natural luxury commodities that could be used and promoted to the economic and environmental advantage of Hawai'i as well as of the people who live in Hawai'i.

Finally, the market for aloha-wear, and shirts with Hawaiian influence, is substantial. In the Neiman Marcus and other high end stores in Hawaii, one can find shirts in the several hundreds of dollars that might not carry any special intrinsic value to them as they would if they were made form locally grown and manufactured materials, and yet these stores are still selling these products! If hemp were another product that was grown in Hawai'i, it could provide some of the same features that these other raw resources bring to their products, and could be marketed with this unique offering, all the while, supplying the consumers with what they really want and easing the textile import burden of Hawai'i.

Figure 7.6

Figure 7.6 shows a mock logo for the concept of Hawaiian hemp

In support of starting a local sustainable Hawaiian textile industry, some of Hawai'i's current designers such as Kini Zamora, Page Chang, and Bill Keoua Nelsen, as well as several future designers coming out of the University of Hawai'i at Mānoa Fashion Design and Merchandising department now, such as Jennifer Bright, Moses Gouveia, Krystal Ann Cabo, Lucas Armand Bertrand and more have indicated an interest in using Hawaiian made sustainable textiles in their future designs.

Interestingly enough, the primary target markets probably share similarities and crossovers for each of these products. One could easily imagine a person who lives in Hawai'i and wants to support the local economy and environmental aspects of the state, or an affluent tourist, sitting at a local Hawaiian coffee shop and wearing a koa wood watch while drinking Hawaiian coffee and eating Hawaiian chocolate covered macadamia nut shortbread cookies, just came out of a spa that uses kukui oil products on their clients, and is shopping for locally produced sustainable luxury apparel. In fact, this is exactly the kind of clientele that Wear on

Earth will ideally have; a modern consumer that makes decisions and purchases based on psychographic ideals.

Chapter Nine: Objective 4 Wear on Earth Design Philosophy

Figure 8.1 illustrates some Wear on Earth designs in a digital format.

Marketing Hawaiian Textiles to the world much like Chinese Silk, Egyptian cotton, or like Swiss Chocolate, and French Champagne, will help to solidify it as such in the minds of the world's consumers. In this way Hawaiian Hemp, for example, could gain and retain its value as a commodity in general, but then when this valuable commodity is used to create other Hawaiian commodities, then the total product viability and sustainability comes into play. These products would be exclusive to Hawai'i; grown and sewn in Hawai'i from 'seed to shelf'. Sustainable products produced in Hawai'i are what tourists are looking for, and what consumers in general will be looking for into the future. For Wear on Earth, locally made and sustainable textiles are necessary for this reason; the entire purpose for Wear on Earth to exist is to be able to positively contribute to the community. Sustainable fashion is fashion that focuses on the environment and the social responsibilities involved, taking all things into consideration; the process of making garments, in the design of the garment from fiber to finish, as well as in the modus operandi of the business. Wear on Earth Hawai'i fashion boutique's goal is to focus and promote sustainable fashion, see figure 8.1.

Mission Statement for Wear on Earth

To provide the finest quality sustainably manufactured product, without causing further damage, by creating a business that highlights critical environmental concerns and inspires solutions to these global crises through product design and education, while respectfully, responsibly, and ethically meeting the needs of all parties involved, and give back to the communities that host and inspire Wear on Earth.

The design philosophy is all about looking to nature and the local environment for the inspiration, and company direction, to be able to effectively become a part of the solution directly through the use of particular designs, product specifications, educational campaigns based strictly on the inspiration, see figure 8.2. Wear on Earth would like to be a top quality brand but based on a new set of criterion for 'Top,' as issues such as sustainability, pollution, over-population, global warming, and starvation concerns begin to have greater effect on the choices and the evolving value perceptions that the world population cultivates. For example, if more cropland that is used for fast fashion textile crops could be used for food crops, there might be more food to contribute to areas of need.

Figure 8.2 shows a portion of an illustrated 2016 Resort Plus Size Collection that is inspired from Hawaiian Gastropods.

Wear on Earth will offer stainable and organically manufactured clothes for women and men that physically look attractive and physically feel good to wear, and psychologically feel good to wear, with design, manufacturing, and sales emphasis and philosophy that are based on supporting and nurturing the local environment as seen in figure 8.3 which show designs that are inspired by the Hawaiian flora, such as palms, ki plant, ferns and kalo. In order to support this, the garment designs are intended to be transcendent of momentary fads and focus rather on the desired longevity of the quality garment's application across longer periods of time. This is a huge split from the other current trend in fashion that is now called, 'fast-fashion,' which puts a huge and socially and environmentally detrimental burden on the manufacturing members of the garment industry to produce garments from start to finish in a matter of weeks to satisfy an unnecessarily applied timeline (Kunz & Garner, 2007). Wear on Earth hopes to move away from fast fashion and to be on the forefront of a recently shifting paradigm towards environmental awareness that continues to positively inform mankind's evolution.

A possibility for putting actions towards this goal is to create limited edition collections. This idea is contrary to fast fashion and supports the concept of sustainability, as it is impossible to sustainably supply fast fashion the way it is mass produced and supplied now. These limited edition collections would be made into a limited number of pieces from the beginning, without possibility of reorder or restock. This limited availability concept could engender the idea of value and worth by the rarity and exclusivity alone, not to mention the value added by the elemental nature of the garment; from local materials to local design inspiration, and construction, and in this way create the natural demand that would exist for products of this nature.

Ideally all manufacturing for Wear on Earth will occur locally and organically from seed to end product as would be required for ultimate sustainability. As the Hawai'i textile industry is not in existence, private investors looking into these particular areas of interest will need to create the industry itself; farms need to be planted, equipment purchased, vacant warehouses leased and prepared, two or three yarn mills would need to be opened, one or two textile mills would need to be opened, and employees hired in order to make this happen. Since there is already a garment manufacturing industry in Hawai'i, less initial investment would be needed in this area to satisfy the requirements of an exclusive local fashion industry, and due to the advances in technology in these fields, new and cleaner yarn spinning and textile manufacturing equipment is now available for industry use. Feasibility research into the textile industry processes and needs for Hawai'i is already underway, but initially looks promising.

Figure 8.3 shows a portion of a collection featuring Hawaiian palms, maidenhair fern, ki, pencil urchin, plumeria, and various kalo.

Wear on Earth garments must be made from sustainable textiles in order to fulfill the company goals, but the other necessary aspect to the plan, is that the garments directly reflect the location where they are made, intrinsically and extrinsically. Wear on Earth garment designs are literally inspired by the species of this island chain, more specifically, the indigenous, culturally important, and the endemic and endangered species. In order to be able to effectively contribute back to the community, Wear on Earth product prices will be above market price. The cost of each garment will be whatever is necessary to ethically and responsibly pay for its creation. Clients, who have a psychographic motivation, will have the option to donate further, knowing that a significant portion of the production value of Wear on Earth Hawai'i merchandise will go to the recovery and continuation of threatened and endangered species in Hawai’i; from which the design is so inspired. The price tag will offer the client two or three price options in ascending order offering the consumer an opportunity to choose to donate to the restoration of that particular endangered species or community cause. A regular client will gladly pay the cost, but people who live in Hawai'i who have above average income would potentially more, because in return for the high monetary cost of the items, customers will have the opportunity to gain far greater value for their purchase than just a beautiful, locally and sustainably made, and well-crafted item. They will know that they have contributed positively and directly to a much greater cause (community and environmental sustainability) and can take pride in their decision to do so. There will exist the possibility for the consumer to feel a greater depth of personal responsibility and presence by owning and wearing these items, perhaps, than any other 'name brand' can offer them, because there will literally be more to the garment than just a name. The name and logo of Wear on Earth will truly represent a total concept of responsibility, sustainability, quality, longevity, and legacy. Figures 8.4 and 8.5 illustrate designs inspired by rare Hawaiian butterflies as well as endangered Hawaiian birds.

Figure 8.4 shows a portion of a collection inspired by Hawaiian butterflies.

Figure 8.5 shows a portion of a collection inspired by endangered Hawaiian birds.

This is also why the brand is named Wear on Earth, and not a person’s name, or initials, because the belief is that the natural inspiration from whence the designs are derived is greater and more beautiful than anything else comparatively, and so damage to the concept and the product would be done by 'tagging' it with a personal name, see figure 8.6. It must be able to stand alone as an icon that represents more than just the garment or the company, it needs to represent a positive awareness and shift in social consciousness, a positive change in the social archetypes of demand.

As humans, we have an opportunity to sustainably retreat from the previous and thoughtless damage the textile industry has caused this planet if we try! There is a time in our near future when many more people in Hawai'i will have the opportunity for employment that was not present before. These people will be able to take pride in what they do, take home a fair remuneration for their efforts and products, and successfully feed their families and pay their bills, knowing all the while that they are positively contributing to a far greater cause than any individual could manage. Sustainable fashion offers one path towards this vision. This is my goal and will be my quest until resolution can be attained.

Figure 8.6 shows a portion of 2016 Spring Collection Bathing Suits: Hawaiian Butterfly fish: Chaetodontidae

Appendix

ASTM D 1230 Flammability of Apparel Textiles

Objectives:

As stated in the ASTM 1230 guide manual, this test method covers the evaluation of the flammability properties of most natural and synthetic textile fabrics. This standard should be used to measure and describe the properties of materials products or assemblies under actual fire conditions, however, results of this test may be used as a fire risk assessment of the fire hazard of a particular end use.

Methods:

Two factors are measured in this lab. The first recorded data is the ease of ignition time, which is how fast the sample catches on fire, and the second measurement is the flame spread time which is the amount of time it takes for the flame to spread a certain distance. For this lab, the flame spread time was determined by the fabric sample itself, meaning when the flame extinguished its self, or of the fabric would not burn. All specimens are considered raised and none of them have been dry-cleaned. Some deviations were necessary; 1) no oven or desiccator was used, instead the specimens were conditioned in a room set to 63° for four hours prior to the test, and 2) the butane was not connected to the Flammability tester machine and so a 'fireplace' lighter was used instead. Additional consideration was given to the surface of the specimens, as they were smoother on one side. This side was presented as the face and was also considered to be a raised surface. Specimens were cut with the 'warp' fiber direction running the length of the specimen pattern if a warp trend was noted.

According to section 12 of the ASTM 1230 instruction manual, the class determinations used in this lab are those used by the Consumer Product Safety Commission for interpreting the results of a similar test. They are simplified as follows: Class one textiles are considered by the trade to be generally acceptable for apparel, but are limited, class two textiles are considered by the trade to have flammability characteristics, and class three textiles are considered by the trade to be unsuitable for apparel.

Materials:

- 45º Flammability Tester Machine and specimen frames with clips
- 4 kapa specimens
- Recording video device with timer

Procedure:

1. Put the pre-cut and conditioned specimen measuring 50mm x 150mm into a specimen holder and lock it into position
2. Put a holder with specimen into position inside the burning apparatus at a 45 degree angle.
3. Apply a standardized flame to the surface at the lower end of the specimen.
4. Record the amount of time it takes for the specimen to BEGIN to burn from the point the flame touches the specimen.
5. Record the time from the point the specimen catches on fire to the point of flame spread for each specimen.
6. Record the specimen's burning activity, residue, and if or not it continues to burn.

Hypothesis:

1. The light weight kapa will burn the fastest and the heavy kapa will burn the slowest.
2. No kapa specimen will be determined as a class one textile.

Results:

Results indicate that hypothesis one was supported. Table **A** shows the ignition time, the time of flame spread over the specimen, and the class determination of the kapa. With the increased weight of the specimen, the flame spread time slowed. All of the specimens experienced a flame spread that was slow enough to determine them as class one textiles.

Table A

Specimen	Weight (g)	Time to ignite the specimen (sec.)	Flame spread over entire specimen (sec.)	Continuation	Class Determination
1	0.50	0.80	9.44	Yes	Class I
2	0.82	1.07	13.98	Yes	Class I
3	1.55	1.55	32.95	Yes	Class I
4	1.03	2.20	19.44	Yes	Class I

Table A shows the ignition time, the time of flame spread over the specimen, and the class determination of the kapa

Contrary to hypothesis two, the data gleaned from this test reveals that kapa made from both paper mulberry and hemp are both classified as textiles that can be used in garments suitable for regular use according to the nature of the flammability of the kapa as a textile. Table **B** illustrates the specimens' burning patterns, if any remaining textile structure is evident, and the consistency of ash residue. This information could be useful in helping to determine if a particular thickness or watermarking may be less flammable or have a slower flame spread time than others.

Table B

Specimen	Whole specimen after burning	Detail of specimen to show edge of burn and textile structure in the ash	Detail of ash to show consistency of ash
1			
2			
3			
4			

Table B shows the burning patterns of the kapa specimens

Discussion: These specimens were tested as directed in the ASTM Test Method D 1230 Flammability of Apparel Textiles manual. For all specimens, the flames extinguished themselves, but the coal at the edge of the textiles continued to burn and consume until it also eventually extinguished itself. All specimens also shared a similarity of flame color in that the flame was orange at the base, white in the middle with a reddish hue on top, the notable exception being that the hemp specimen also showed a magenta tone to the flame. The size and the spread of the flames behavior, however, were different for each specimen. For the lightweight kapa, the flame extended itself well above the top of the specimen tray and burned quickly because of this elevated flame height. It sent lightweight ashes with burning coals up into the surrounding air which could contribute to a flame spread time and when burned out, the fiber structure was still partially evident in some places along the edge. The flame from the medium weight kapa was much smaller in height and width, in comparison, and so also demonstrated a slower burn time by almost six seconds than the lightweight kapa. It had a heavier ash residue that still sent coal particulate into the air, but did not offer much in the way of remaining textile structure along the burnt edge. The heavyweight kapa exhibited a smaller narrow flame and the burn time was more than two times of that of the medium weight kapa. The ashes were much heavier and did not stray as much in the testing box and the specimen did not exhibit any remaining structure in the residual ashes. The hemp kapa specimen had a flame spread time that was in between the medium weight kapa and the heavyweight kapa flame spread time. The hemp flame started out smaller than all the other flames, but soon continued to grow in height and width.

The smoke produced from all of the specimens was also similar to each other. It was predominantly white and thin, and smelled like wood in a fireplace or paper burning, but there was more smoke per more substance being burned, the heavyweight kapa offering the most. Additionally the hemp had a slightly sharper burning wood smell over the kapa which mostly smelled like burnt paper. For all specimens the residual ash was thin and wispy and for the most part, did not retain any of the textile structure, suggesting a thorough burn of the fiber; however some slight structure was noted in the first lightweight kapa specimen as well as the hemp specimen.

In conclusion, This test does not imply that a class one determination rating for the flammability of these kapa specimens is making any other statement about the nature of the kapa textile in regards to strength or other properties it may or may not possesses relating to the standards of regular garment use. This data may be more suggestive to the flammability properties of the particular fibers more than the construction of the textile; however, further tests with greater variation of kapa, as well as the woven textile versions of these fibers, would need to be conducted to explore this.

ASTM D 1388 Standard Test Method for Stiffness of Fabric

Objectives:

As stated in the guide manual, the purpose of the ASTM 1388 Standard Test Method for Stiffness of Fabric, is to determine the flexural rigidity of any textile. This testing method is pertinent to the textile industry and also relevant because it helps designers, manufacturers, merchandisers and consumers know whether the stiffness of a specific fabric is suitable for end use design and performance of the garment or product.

Methods:

The purpose of this test is to measure the stiffness and bending properties, also known as the "hand" of textiles. These measurements will be found performing the cantilever test; which prompts the fabric to bend under its own mass. In this way, the rigidity or stiffness, which is revealed as a weight of mg per cm^2 on the textile, will be calculated. Because there was not enough actual kapa textile available to make the multiple specimens needed, only one specimen per each weight category was used and one measurement was taken from each specimen.

Materials:

- Cantilever Bending Tester placed on a level platform

- 4 Kapa specimens

Procedure:

1. Place the specimens on the balance scale and record the weight data in milligrams.
2. Measure the area of the test specimens and record the data.
3. Place a specimen on the Cantilever Bending Tester. Place the weight on the sample and turn the lever at a consistent rate until the edge of the sample strip touches the angled edge.
4. Record the specimen's overhang length in cm on the Cantilever Bending Tester.
5. Repeat the steps above for the remaining specimens.

Calculations:

To find bending length, c = o/2

Where: c = bending length, cm

o = length of overhang, cm

To find flexural rigidity, G = W x c^3

Where: G = flexural rigidity, mg cm

W =Fabric mass per unit area, mg/cm^2

c = bending length cm

Hypothesis:

1. The stiffness will increase with the weight of the sample.
2. Hemp kapa will be the stiffest.

Results:

Both hypotheses were supported by this data. The hemp specimen was the heaviest and also demonstrated by the numbers that it has the highest rigidity of all the specimens. These test results and readings indicate that the textile kapa is variable in its stiffness, but that it is so stiff that it pushed the machine to its possible limits. Only the lightweight kapa specimen reached the blade edge used for measuring the angle, and that was straining the outermost possibilities of the machine. It can also be interpreted from this lab data that the hemp fibers provide the stiffest rigidity for the kapa style textile, but that the thickness of the textile can offer great variation of stiffness in addition to the fiber type. As only one specimen type of hemp kapa was tested, its results are compared to those of the kapa made from paper mulberry. Table **C** shows that hemp offers the most rigidity by the numbers, but that heavyweight paper mulberry is the stiffest visually by the angle of bend.

Table C

Specimen	Angle of bend (Degrees)	o cm = length of overhang	Weight (mg)	Area cm^2	W = mg/cm^2	c = o/2 bending length cm	c^3 cm	G = flexural rigidity, mg cm
1	45°	12.07	360	47.5	7.58	6.04	220.35	1,670.25
2	28°	13.67	540	47.5	11.37	6.84	320.01	3,638.51
3	5°	13.97	650	47.5	13.68	6.99	341.53	4,672.13
4	18°	13.97	700	47.5	14.74	6.99	341.53	5,034.15

Table C shows that hemp offers the most rigidity by the numbers

This rigidity is an overall quality of newly pounded kapa that has not been worked at all to produce softness and pliability, however due to the nature of the construction technique and the stiffness of bast fibers pulled from bark, kapa has an intrinsically stiff hand. This rigidity is most obviously determined by the fiber type, the thickness of the kapa, the directions of the fiber layers, the newness or if it has been worked, and is very much effected by moisture content. All of the specimens required long amounts of overhang to produce bend, and the heavyweight specimens barely bent at all. Table **D** shows the bend in degrees that were reached by each specimen and illustrates that the heavyweight paper mulberry kapa appears to be the stiffest.

Table D

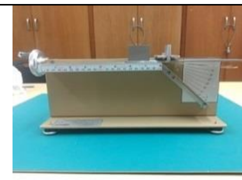
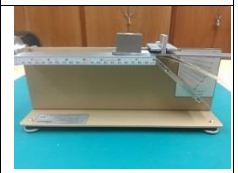
Specimen	1	2	3	4
Photo of specimen on stiffness tester				

Table D shows the bend in degrees that were reached by each specimen and illustrates that the heavyweight paper mulberry kapa appears to be the stiffest

Discussion:

This lab was carried out in accordance with the test method D 1388 Standard Test Method for Stiffness of Fabric by using the cantilever test method. Additionally, specimens were cut according to the fit of the specimen test pattern on the allotted textile for the test, and not in relation to any grain that may be present as a result of the intrinsic nature of the pounded bark-fiber cloth. For the future designer looking to use kapa, this test would be of particular interest in helping to establish a rating for various kinds of kapa and the expectations behind those ratings. The data from this test would help how to select and how to determine if the textile was appropriate to the end use of the particular product.

ASTM 1424 Tearing Strengths of Fabrics by Falling Pendulum type Elmendorf Apparatus

Objectives:

ASTM D 1424 determines the tearing strength by the resistance of a fabric in grams or pounds of force required to propagate a single rip/tear starting from a cut in a fabric using a falling pendulum type Elmendorf Tearing Tester apparatus.

Methods:

According to the ASTM D 1424 manual in section 4.1, specimens that have been prepared are torn to provide the tearing resistance factor, which is calculated using the pendulum reading and the pendulum capacity. Only one of each specimen type was hand-cut cut from the sample sheet provided according to figure one in the manual.

Materials:

- Thwing-Albert Falling-Pendulum (Elmendorf) Type Tester used is 32 lbs. (14.3 kg.)
- 4 kapa specimens

Procedure:

1. Position the pendulum in raised, locked position and position pointer to its zero-force position.
2. Mount the long end of specimen with slit in long side centered in between the edge of the stationary clamp and the edge of the pendulum clamp, and the notch facing up. Close the clamps, securing the specimen with approximately equal tension on both clamps.
3. Depress the pendulum stop to release pendulum, allowing the pendulum to complete its forward swing.
4. Catch pendulum just after mid-backward swing and return it to its raised, locked position being careful not to disturb the position of the pointer.
5. Record the scale reading required to completely tear specimen. Reject readings obtained where the specimen slips in the jaw or where the tear deviates more than 0.6cm away from the projection of the original slit. Note when puckering occurs. Record if tear was crosswise to parallel direction of tear, or if specimen is not tear-able.

6. Remove torn specimen and repeat with following specimens.

7. When all data is collected, calculate the tearing force using this equation:

$\mathbf{F_t = R_s \times C_s/100}$

Where F_t = tearing force, cN (gf) or lbf

R_s = scale reading

C_s = Full Scale Capacity

Hypotheses:

1. Nonwoven textiles will require less force to tear than woven textiles.

2. The force required to tear should increase with the weight of each specimen.

Results:

Table **E** reveals that in this particular lab, the heavyweight paper mulberry kapa actually required the most force to tear at just over four pounds.

Table E

Specimen	Weight of Specimen	Pendulum Scale Reading	Tearing Force = F_t lbf
1	0.49 g	5	1.60 lbf
2	0.73 g	7	2.24 lbf
3	0.90 g	13	4.16 lbf
4	1.01 g	3	0.96 lbf

Table E reveals that in this particular lab, the heavyweight paper mulberry kapa actually required the most force to tear at just over four pounds

Hypothesis one was supported by the data for all of the kapa specimens, but the only way to test it was to compare these test results with those of woven specimen, by using the results from a previous lab testing woven specimen that had been done by the same operator on 2/03/2014. To make the comparison, only the dry specimens were evaluated and the tearing force of the two samples was averaged. Table **F** shows the tearing force from the average of the warp and weft from dry specimens, and reveals that kapa textile sits on the lower end of the scale of force needed to tear the various textiles tested in this lab.

Table F

Specimen	Warp Scale Reading	Weft Scale Reading	Average warp and weft F_t lbf
Maroon Cotton	12	11.25	3.72 lbf
Black Polyester Cotton	13	13	4.31 lbf
Black Silk	11.5	68	12.72 lbf
Blue Acetate	17	14	4.96 lbf
Purple Polyester Peach-skin	84	18.5	16.40 lbf
Black Wool	13	85	15.68 lbf
Blue Rayon	9	14.5	3.76 lbf
Grey Nylon	20	59	12.62 lbf
Black Polyester	24.5	25	7.92 lbf

Table F shows the tearing force from the average of the warp and weft from dry specimens

In relation to hypothesis two, the paper mulberry performed as expected and the hypothesis was supported. Each of the paper mulberry specimens showed an increase in force necessary to tear the specimen in relation to the increase in weight, however, hypothesis two was not supported by the numbers data from the hemp specimen, even though it recorded the greatest weight of the specimens tested in this lab. It is possible that this number data is not quite accurate of the overall textile, but simply one possibility of many outcomes that need to be interpreted; considering that the tear of this specimen took a hard turn at an early moment and went the path of least resistance. For this particular hemp specimen, it was cut in such a manner that somewhat represented the strength of the warp fibers, yet due to the nature of the construction of the kapa textile, no real weft fiber format was represented, and so the tear required almost no force to make in what would have been against the weft fibers; the warp fibers were not torn. As can be seen in table **G**, one can see the perpendicular tears on specimens one and four indicating the strength of fibers and weakness of textile structure. In this case, the data may be indicating the weakness of the structure of the cloth; because the nature of the kapa cloth itself is somewhat delicate, not having any crosswise fibers added to the textile during construction, and because the physical specimen and photo data suggest that the hemp fiber is actually incredibly strong; resistant to the tearing at all. Table **G** shows the grain and tearing tendencies of these kapa specimens. The heavyweight kapa demonstrates a 45 degree tear which indicates a good mixture of cross grain fibers and thickness of kapa produces a stronger textile.

Table G

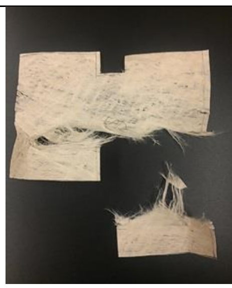
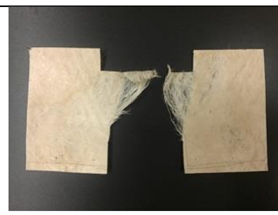
Specimen	**1**	**2**	**3**	**4**
Photo of specimen				
Tearing tendency of specimen	Tear at 90° angle does not go across the warp-like fibers showing their considerable strength	Tear goes through the middle of the specimen but exposes the layered construction of this specimen	Tear at a 45° angle showing strength of fiber and thicker construction of this specimen	Tear at 90° angle does not go across the warp-like fibers showing their considerable strength
Grain tendency of specimen	Warp dominant and weft cross-hatched layered grain	Warp and weft cross-hatched layered grain	Warp and weft cross-hatched layered grain	Warp dominant layered grain, some cross-hatching

Table G shows the grain and tearing tendencies of these kapa specimens

Discussion:

This lab was tested according to the ASTM D 1424-96 (Re-approved 2004) Standard Test Method for Tearing Strength of Fabrics by Falling-Pendulum Type (Elmendorf) Apparatus. This particular test has revealed that the kapa constructed using the current methods of making kapa, using these two fiber possibilities, has a limited strength ability as a textile designated for regular use, because of the structure of the textile and not because of the nature of the fiber itself. Paper mulberry and hemp have both been used by the Chinese for centuries as spun and durable woven textiles (Needham & Wang, 1954). It is the lack of a woven structure that is showing the weakness of the textile. When compared to woven specimens, in terms of force needed to tear the textiles, this lab may suggest that great textile strength is achieved from spinning fibers into yarn and weaving yarn into cloth. It also poses the question of how to increase the strength of the non-woven textile; which might be answered somewhere in the process of making the textile. This presents an opportunity for an explorative process between a kapa maker and an ASTM tester to discover a method of making this textile that would better stand up to testing and increased consumer usage.

ASTM D 4970-02 Standard Test Method for Pilling Resistance and Other Surface Changes of Textile Fabrics: Martindale Tester
and
ASTM 4966 Abrasion Resistance of Textile Fabric with the Martindale Abrasion Method

Objectives:

The Standard Test Methods for Pilling Resistance and Other Surface Changes of Textile Fabrics, as well as the Abrasion Resistance of Textile Fabrics Test Method both use the Martindale Abrasion Tester to determine the pilling and abrasion resistance of textile fabrics. These methods are applicable and relevant to the textiles industry because they show whether or not a fabric is suitable for specific uses as well as to help companies to better estimate the life and quality of their products.

Methods:

These labs determine and rate the difference in surface changes and the mass by percentage of mass lost due to abrasion. Small fabric specimens are cut and mounted onto the Martindale Tester. Each specimen should be faced out in the testing machine and facing the standard abrasive fabric. The face of the test specimens are rubbed against the abrading fabric, in the form of a lissajous figure which represents sixteen movements of the machine, for 25,000 rotations. The degree of the fabric abrasion or surface appearance change produced by this action is then evaluated. This method of testing the fabric's resistance to abrasion is not recommended for acceptance testing.

Materials

- Martindale Abrasion Tester
- ASTM 4970 Pilling chart to rate observations.
- Standard Abrading Fabric 5.5 in
- Fabric Punch 1.5 in (38mm)
- 4 kapa specimens (each cut in a 1.5"circle)

Procedure

1. Mount abrading fabric circle to testing tables.
2. Cut one circle measuring 1.5" of each test specimen
3. Weigh each test specimen circle for its pre-abrasion weight.
4. Place the disk of 3 mm polyurethane foam and specimen of the same fabric in each of the holders, making sure the face of the fabric is exposed for all specimens.
5. Place the specimen holders into the machine and insert a spindle into each specimen holder to give pressure on the larger specimen of approximately 9 kPa.

6. Set the machine to the appropriate test setting and then start the machine and let it run for the specified time; 100 movements for the pilling test and 25,000 rounds for the abrasion test. The standard speed of the Martindale Tester was 47.5 RPMs.
7. At 100 movements, stop the machine and record observations and results and compare to the Pilling chart below.
8. Restart the machine to complete the abrasion test.
9. Periodically examine the samples. If a sample should get a hole, stop its abrasion process. Use the following chart, see figure A, from the ASTM 4970-02 Standard Test Method to rate the specimens for the pilling test.
10. Re-weigh each test specimen for the abrasion test.
11. Record observations and results. See tables G and H.
12. Use the following equation to make the calculations for abrasion test option three to get the percentage of total loss: **[(A – B)/A] x 100.**

    Where: **A** = before weight, **B** = after weight

    Figure A

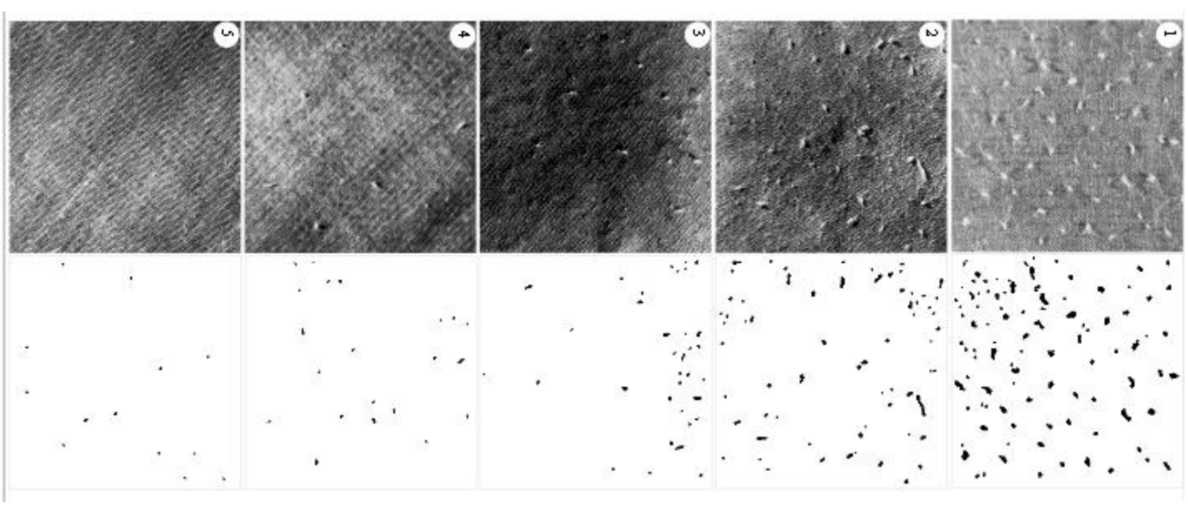


Figure A

Hypotheses:

1. The lightweight kapa will show evidence of pilling and abrasion before the heavy weight kapa.
2. None of the kapa specimen will make it through the full 25,000 rounds.

Results:

Hypothesis one was supported in that the lightweight and medium weight kapa developed significant pilling by 100 rounds. The hemp kapa also developed stray fibers more than pilling. The heavyweight kapa appeared to be mostly unaffected at 100 rotations. Table **H** shows the pilling rating according to the ASTM 4970-02 pilling chart, that the lightweight specimen ranked a **1**, which is the most pilling according to the pilling scale provided, see figure A. The heavyweight kapa ranked a **5** which is the least amount pilling.

Table H

Specimens	**1**	**2**	**3**	**4**
Specimens before abrasion				
Specimens after 100 rounds				
Pilling rating **1**= most **5**= least	**1**	**2**	**5**	**2**

Table H shows the pilling rating

Next, the percentage of loss of the specimen from the abrasion test can be seen in table **I**, which illustrates that the lightweight kapa showed the least percentage of loss at about 18% but was the first to be completely worn out and destroyed and needed to be removed after only 1,700 rounds, which might be due to the structure of the kapa and if or not it was watermarked or what kind of watermarking. The medium weight kapa expressed the greatest percentage of loss at just over 33%, and needed to be removed after only 2,000 rounds. This could be a result of the thickness of the specimen and the fineness of the fibers; meaning that the textile was heavy duty (thick) enough to withstand a longer duration of the test, which is what caused the greater percentage of fiber loss. The hemp specimen was again subject to its own fiber strength, which in this case made the situation worse. In the case of this specimen construction structure, it eventually gave way along the lines of least resistance and because of the strength of the fiber; it tore instead of thinning from abrasion which made a flap that wore off after 300 rounds. The heavyweight kapa lasted the longest of all four specimens, not developing any significant abrasion until 3,000 rounds but then the bulk of abrasion seemed to happen all at once in the last 600 rounds before removal from the machine at 3,600 rounds, and lost a total of just over 22%. Table **I** shows the percentage of weight loss per specimen after the total rotations necessary to make holes in the specimen.

Table I

Specimen	Specimen weight before test	Specimen weight after test	Percentage of difference
1	0.11	0.09	18.18%
2	0.12	0.08	33.33%
3	0.18	0.14	22.22%
4	0.16	0.11	31.25%

Table I shows the percentage of weight loss per specimen after the total rotations necessary to make holes in the specimen

Even though the numbers tell a detailed story, the visual perspective in table **J** will be very useful, in helping to understand the process of abrasion as it applies to kapa in particular. Table **J** shows the visual rate of abrasive decay per specimen as the test continued. The lightweight kapa began to pill and show surface changes almost immediately, while the heavyweight kapa proved to be the best performer for this test, requiring almost 2,500 rotations before any real damage was noticed. The strength of the hemp fibers caused a tear which destroyed the specimen.

Table J

Specimen	300 rotations	1000 rotations	1700 rotations	2000 rotations	3600 rotations
1					
2					
3					
4					

Table J shows the visual rate of abrasive decay

Discussion:

This lab was tested according to the ASTM D 4970-02 Standard Test Method for Pilling Resistance and Other Surface Changes of Textile Fabrics: Martindale Tester and ASTM 4966 Standard Test Method for Abrasion Resistance of Textile Fabric with the Martindale Abrasion Method. Kapa has not been tested in this manner before, to current knowledge, and as it is one of Hawai'i's premiere art textiles that are experiencing a renaissance, according to Page Chang, a Hawaiian kapa maker and artist, this test is/will be particularly relevant to understand how kapa may respond to more modern applications and uses. Kapa makers, or designers who wish to make or incorporate kapa into their designs, will be able to provide and apply this knowledge to labeling information regarding proper care for increased longevity for the life of the product.

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